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No. 105, ORIGINAL

In The

Supreme Court of the United States

STATE OF KANSAS,

Plaintiff,

v.

STATE OF COLORADO,

Defendant,

and

UNITED STATES OF AMERICA,

Defendant-Intervenor.

ARTHUR L. LITTLEWORTH, Special Master

FIFTH AND FINAL REPORT

VOLUME III

APPENDIX C TO PROPOSED
JUDGMENT AND DECREE

January 2008

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APPENDIX C.1

Hydrologic – Institutional Model

Model Documentation

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1. General Description of Hydrologic-Institutional Model

1.1. *Introduction*

The Hydrologic-Institutional Model (H-I Model) is used to determine depletions and accretions to Stateline flow caused by Groundwater Pumping and Replacement. The H-I Model simulates the hydrologic and institutional systems that occur along the Arkansas River between Pueblo, Colorado, and the Colorado-Kansas Stateline (Stateline). The simulated hydrologic system includes both surface water and groundwater. The simulated surface water component includes native streamflows of the Arkansas River, transmountain deliveries, tributary inflows, reservoir operations and irrigation diversions. The simulated groundwater component includes the effects of well pumping and recharge in alluvial and surficial aquifers. The simulated institutional system includes rules that govern the diversion of surface water under the priority system in Colorado, the operation of John Martin Reservoir under the Arkansas River Compact and resolutions of the Arkansas River Compact Administration, and the operation of other off-channel reservoirs and Replacement operations, except for the credit derived from operation of the Offset Account. The H-I Model predicts diversions, streamflows and storage of water in and releases of water from John Martin Reservoir and off-channel reservoirs. The H-I Model is currently calibrated over the period 1950 through 1994 to historical diversions and streamflows. The H-I Model simulates the period

1950 to the present. Additional years are added to the H-I Model by extending the input data sets.

Historical groundwater pumping, transmountain deliveries and water supplies that are used to replace well depletions (Replacement water supplies), except those for which the credit is derived from the operation of the Offset Account, are included in one H-I Model run to simulate actual historical conditions. This run is referred to as the "Historical" run. In a separate run of the H-I Model, post-compact groundwater pumping, transmountain deliveries and replacement water supplies are removed and groundwater pumping is limited to the pre-compact pumping allowance of 15,000 acre-feet per year to simulate diversions and Stateline flows that would have occurred under those conditions. This run is referred to as the "Compact" run. The difference in Stateline flows between the Historical run and the Compact run is considered to be a depletion or an accretion to Stateline flows with respect to Groundwater Pumping and credit for Replacement water supplies included in the H-I Model. The Durbin Usable Flow Method with the Larson coefficients (see Appendix C.2 of this Decree) is used to determine whether depletions and accretions to Stateline flow determined using the H-I Model are depletions and accretions to Usable Stateline Flow.

This narrative describes the hydrologic setting and the institutional framework of the H-I Model, the major components of the H-I Model program, the input required for the H-I Model and the H-I Model

outputs. Agreements signed by the Colorado State Engineer and the Kansas Chief Engineer and / or signed by counsel for the States to settle disputed issues related to H-I Model operation or inputs are included in other Appendices to the Judgment and Decree (Decree).

An electronic copy of the H-I Model code, input data files, pre-processing and post-processing programs, calibration programs and H-I Model output are included on the attached DVD. This narrative is intended to describe the H-I Model as accurately as possible; however, if any description or representation of the H-I Model in this narrative conflicts with the code, data files, processing programs, calibration programs, or H-I Model outputs on the DVD, the information on the DVD will control.

Colorado
Kansas
New Mexico
Oklahoma
Pueblo
CROWLEY CO.
KIOWA CO.
PUEBLO CO.
OTERO CO.
BENT CO.
PROWERS CO.
Las Animas
Lamar
Coolidge
Garden City
Fountain Creek
Adobe Creek
Big Sandy Creek
Horse Creek
Arkansas River
Apishapa River
Crooked Arroyo
Huerfano River
Purgatoire River
Two Butte Creek
Legend
Model Domain Area
Arkansas River Basin
0
12.5
25
50 Miles
Kansas Department of Agriculture
Administrative Services, GIS
January 28, 2008

1.2. *Hydrologic Setting*

1.2.1. Arkansas River Basin

The Arkansas River Basin above the United States Geological Survey (USGS) streamflow gage near Coolidge, Kansas (USGS Gage Identification No. 07137500), encompasses a drainage area of 25,410 square miles. See Figure 1. Streamflow in the basin is derived mainly from the melting of snow that accumulates in the Colorado Rocky Mountains between October and May each year. Although tributary inflows from intense thunderstorms occur along the foothills and on the prairie, rainfall runoff typically contributes little to the normal flow of the river.

In Colorado the main tributary is the Purgatoire River, which joins the Arkansas from the south at Las Animas just upstream from John Martin Reservoir. The Purgatoire originates high in the Sangre de Cristo Mountains about 40 miles upstream of Trinidad. Like the mainstem, it is fed by runoff from melting snow, and above Trinidad the flows are perennial. The other major contributors to the Arkansas from the south are the St. Charles, Huerfano and Apishapa Rivers. The flows from these streams are intermittent and come primarily from intense summer rainstorms, although the drainage area of each of these streams includes some mountainous regions.

The major Colorado tributaries from the north are Fountain, Adobe, Horse and Big Sandy Creeks. These streams also are normally intermittent and dependent upon summer rains. With the exception of

Fountain Creek, these streams drain the high plains territory and are not as productive as the southern tributaries. The bed of the mainstream below Pueblo lies in a broad, sandy and frequently shifting channel. In Colorado, the river channel consists of the "valley fill aquifer." This aquifer fills a U-shaped trough cut into bedrock, which includes shale, limestone and sandstone. The valley fill aquifer, often referred to simply as alluvium or alluvial materials or aquifer, is highly permeable. It ranges in width from about one to fourteen miles, with an overall average width of approximately three miles. Thickness of the aquifer reaches more than 200 feet, but with an average depth of about 30 feet. The groundwater in the valley fill aquifer is in hydraulic continuity with the surface flows of the river. Groundwater and surface water constitute a common water supply. Thus, groundwater supports and contributes to the surface flows of the river and pumping by wells therefore can draw water away from the river.

In certain reaches of the Arkansas River in Colorado, the river alluvium is flanked by bench areas of older, less permeable deposits. These are referred to as "surficial aquifers," or "bench aquifers." These areas are part of the tributary groundwater supply.

Groundwater is withdrawn primarily from the valley-fill aquifer and adjacent bench aquifers along the river. The alluvial and bench aquifers are recharged primarily by infiltration from streams and canals and by percolation of precipitation and applied

irrigation water. The direction of groundwater flow is generally toward the river from the recharge areas, thereby contributing to streamflow.

Groundwater is used in the Arkansas River Valley in Colorado for irrigation, municipal, livestock and domestic water supplies. The major use of water in the H-I Model Domain is crop irrigation. Many surface water right owners in Colorado use groundwater as a supplemental source of irrigation water. Groundwater is also used as the sole source of irrigation water by some water users in Colorado.

Pueblo Reservoir and John Martin Reservoir are large federal mainstem reservoirs and control streamflow in the modeled reaches. Both reservoirs store water for later release. Pueblo Reservoir is used primarily for storage of water imported into the Arkansas River from the Colorado River Basin as part of the Fryingpan-Arkansas Project. The Fryingpan-Arkansas Project was authorized by Congress in 1962. Pueblo Reservoir is the terminal reservoir of the Project and was substantially completed in 1975. Other water is also stored in Pueblo Reservoir, including native water stored under the Winter Water Storage Program (WWSP). Pueblo Reservoir is not included in the H-I Model Domain, and its operations are not simulated in the H-I Model. John Martin Reservoir was authorized by Congress in 1936. The dam and reservoir were completed in 1948. John Martin Reservoir is included in the H-I Model Domain, and its operations are simulated in the H-I Model.

Irrigation is used to sustain agricultural production in the Arkansas River Basin in Colorado and Kansas because of low annual precipitation levels. Most of the irrigated land is located along the mainstem of the Arkansas River. Primary crops include alfalfa, corn, wheat, sorghum and vegetables. Other uses, such as municipal and industrial uses, are relatively small and are not represented in the H-I Model or are specially handled in the H-I Model.

1.2.2. The H-I Model Domain

The term "H-I Model Domain" refers to the geographic area in which the hydrologic and institutional processes simulated in the H-I Model occur, including the groundwater system affected by pumping and recharge. The surface water domain includes the Arkansas River from the points of inflow and diversion that make up the Pueblo Composite Gage (described in the following section) to the Stateline. The groundwater domain includes the valley fill and surficial aquifers along the Arkansas River between Pueblo, Colorado, and the Stateline and is coincident with the Rule 3 area under the Colorado Use Rules. See Figure 2. The irrigated area domain includes the canal service areas of users represented in the H-I Model between Pueblo, Colorado, and the Stateline and the lands irrigated by groundwater diversions from the valley fill and surficial aquifers in the Rule 3 area, together with certain off-channel reservoirs that are outside the canal service areas.

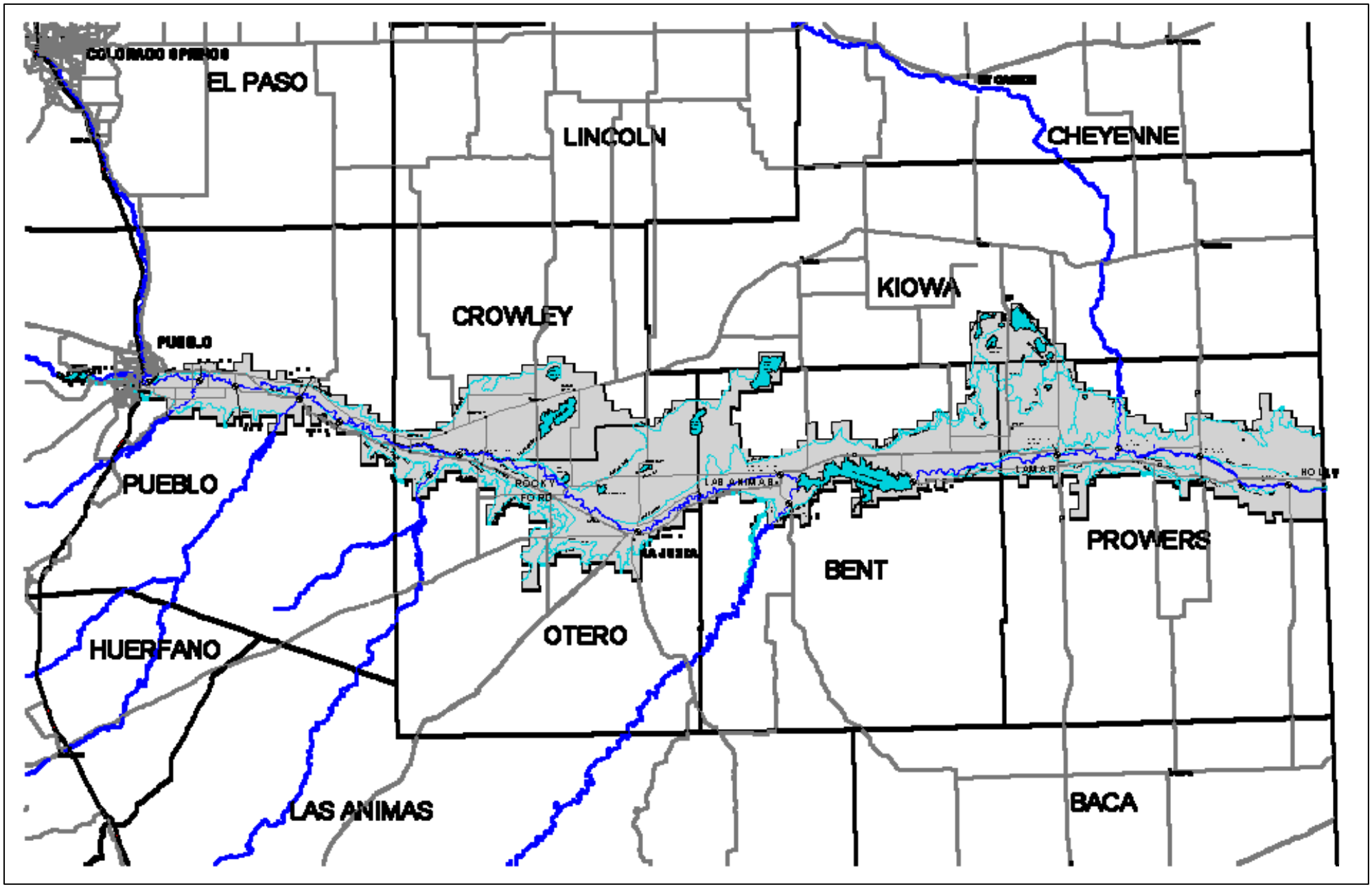


Figure 2. Rule 3 area under the Colorado Use Rules (Source: Map attached to Appendix J.1 of this Decree)

1.2.3. H-I Model Inflows, Outflows, Users and Reaches

The Arkansas River inflows at the upper end of the H-I Model Domain include the sum of streamflows measured at the gage on the Arkansas River above Pueblo (USGS 07099400) and the gage on Fountain Creek at Pueblo (USGS 07106500), Bessemer Ditch diversions (Colorado Division of Water Resources (CDWR) Identification No. 14-533), and wastewater returns from the City of Pueblo's wastewater treatment plant (CDWR 14-620). Diversions by the Riverside Dairy Ditch (CDWR 14-536), the Southside Water Works, the Northside Water Works (CDWR 14-3506) and the Comanche Power Plant (CDWR 14-618) are subtracted from the previous sum to produce a value that is referred to as the Arkansas River at the Pueblo Composite Gage. The streamflow gage above Pueblo was installed in 1965 and is located a short distance downstream from Pueblo Dam. Prior to that time, the Arkansas River gage near Pueblo was used.

The streamflows of the Purgatoire River, as measured at the streamflow gaging station (USGS 07128500) on the Purgatoire River near Las Animas, are also an input to the H-I Model. Additional tributary inflows for gaged and ungaged tributaries are inputs into the H-I Model. These tributary inflows are inputs into the H-I Model into the appropriate model reaches.

The Compact provides that water carried across the Stateline through the Frontier Canal is considered to be part of the Stateline flow (Art. VI-B). Consequently, Stateline flow is the sum of diversions by the Frontier Canal, which are measured at a gage near Coolidge, Kansas (USGS 07137000), and the flow of the Arkansas River measured at the streamflow gage near Coolidge, Kansas (USGS 07137500) Stateline flow is not an input to the H-I Model. Stateline flow is predicted by the H-I Model, and the measured Stateline flow is used to calibrate the H-I Model. Stateline flow averaged 125,087 acre-feet per year over the period 1950-1994, excluding 12 months when floods or spills from John Martin Reservoir occurred.

The portion of the Arkansas River represented in the H-I Model between Pueblo, Colorado, and the Stateline near Coolidge, Kansas is divided into 18 reaches. These are shown in Table 2. Reaches that end downstream at a canal diversion works are listed as extending to below the diversion because the diversion is within that reach. Two additional reaches, 19 and 20, are designated for inflows to two reservoirs as listed in Table 2. Twenty-three users (14 upstream of John Martin Reservoir and 9 downstream) are currently represented in the H-I Model. There are 25 user numbers in the H-I Model. User 25 is the Fort Lyon Storage Canal, which diverts water to Horse Creek Reservoir and Adobe Creek Reservoir, off-channel reservoirs owned by the Fort Lyon Canal Company. No irrigated lands are assigned to User 25

and releases from Horse Creek Reservoir and Adobe Creek Reservoirs are added to the water supply for the Fort Lyon Canal (User 10). User 20 was originally the Manvel Canal, but has been combined with the Lamar Canal (User 18). Thus, there is no User 20.

User numbers are assigned to each ditch or canal that diverts from the Arkansas River and the associated service area. User numbers are assigned to two areas irrigated only by groundwater. Canal service areas range from less than one thousand acres to more than 90,000 acres. Because some water right owners used a common canal to divert water from the Arkansas River or their operations were difficult to separate, they were combined into a single user in the H-I Model, (e.g., the Lamar-Manvel and X-Y Graham). A schematic map of the Arkansas River in the H-I Model Domain showing the river reaches and the users represented in the H-I Model that divert from the river is included as Figure 3. Table 1 lists the user numbers, the user names and the river reaches from which the surface users divert in the H-I Model. Table 1 also includes a list of the reservoirs simulated in the H-I Model. Table 2 describes the reaches in the H-I Model.

Diversions from the river in Colorado are generally made by means of diversion dams and river headgates into canals or ditches. The H-I Model predicts such diversions and associated canal seepage losses. Actual (observed) diversion records are used to calibrate the H-I Model's predicted diversions. Water from the canals is typically delivered to the irrigated

farms via laterals (small ditches or pipelines). The H-I Model estimates off-farm lateral losses. Water delivered to farms for irrigation use is generally subject to on-farm lateral losses, surface runoff (tailwater) and deep percolation losses. The remaining supply, as well as effective precipitation and pumped groundwater (a separate input data set), is available for consumptive use by the crops. The H-I Model simulates consumptive use by crops, soil moisture storage and on-farm losses.

Surface and subsurface losses that are not consumed become return flows to the river or the associated aquifers. The timing and location of the return flows to the river are computed in the H-I Model by using unit response functions that were developed using separate groundwater models.

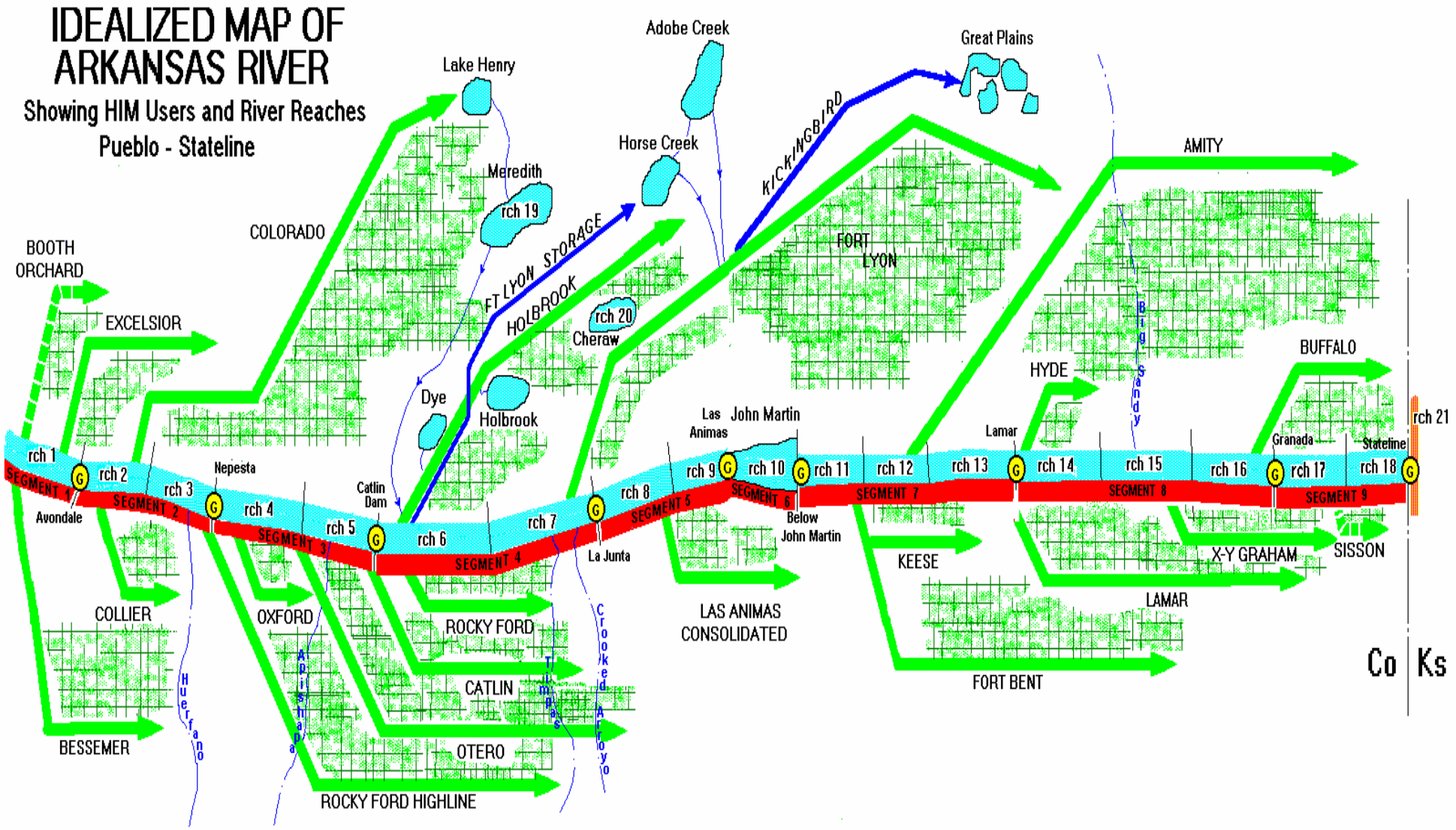


Figure 3. H-I Model Surface Water User Schematic

Table 1. H-I Model Users and Reservoirs

User #	User Name	Diversion Reach
1	Bessemer	1
2	Booth-Orchard	1
3	Excelsior	1
4	Collier	2
5	Colorado	2
6	Rocky Ford Highline	3
7	Oxford	4
8	Otero	4
9	Catlin	5
10	Fort Lyon	7
11	Rocky Ford	6
12	Holbrook	6
13	Las Animas Consolidated	8
14	Groundwater Only Users	
15	Fort Bent	11
16	Keesee	11
17	Amity	12
18	Lamar-Manvel	13
19	Hyde	14
21	X-Y Graham	15
22	Buffalo	16
23	Sisson-Stubbs	17
24	Stateline Groundwater Pumpers	18
25	Fort Lyon Storage	6

Table 1. H-I Model Users and Reservoirs (cont.)

Reservoir #	Reservoir Name	Diversion Reach	Discharge Reach
1	John Martin Reservoir	10	11
2	Lake Henry	2	7
3	Lake Meredith	2	7
4	Dye Reservoir	6	
5	Holbrook Reservoir	6	
6	Great Plains Reservoirs	7	
7	Horse Creek Reservoir	6	
8	Adobe Creek Reservoir	6	

Table 2. H-I Model Reaches

Reach	From	To
1	Fountain Creek	Avondale Gage
2	Avondale Gage	Below Colorado Canal Diversion
3	Below Colorado Canal Diversion	Nepesta Gage
4	Nepesta Gage	Below Otero Canal Diversion
5	Below Otero Canal Diversion	Below Catlin Canal Diversion
6	Below Catlin Canal Diversion	Below Ft Lyon Storage Canal
7	Below Ft Lyon Storage Canal	La Junta Gage
8	La Junta Gage	Below Las Animas Canal Diversion

Table 2. H-I Model Reaches (cont.)

Reach	From	To
9	Below Las Animas Canal Diversion	Las Animas Gage
10	Las Animas Gage	John Martin Reservoir Gage
11	John Martin Reservoir Gage	Below Fort Bent Canal Diversion
12	Below Fort Bent Canal Diversion	Below Amity Canal Diversion
13	Below Amity Canal Diversion	Lamar Gage
14	Lamar Gage	Below Former Manvel Headgate
15	Below Former Manvel Headgate	Below X-Y-Graham Headgate
16	Below X-Y-Graham Headgate	Granada Gage
17	Granada Gage	Below Former Sisson-Stubbs Headgate
18	Below Former Sisson-Stubbs Headgate	Coolidge Gage
19	Lake Meredith Inflow	
20	Lake Cheraw Inflow	

1.2.3.1. Tributary Inflows

1.2.3.1.1. *Gaged Tributary Inflows*

When the H-I Model was developed, only three tributaries to the Arkansas River in the H-I Model Domain had consistent, continuously gaged flow records: Fountain Creek (USGS 07106500), the Apishapa

River (USGS 07119500) and the Purgatoire River (USGS 071285). Gages are now operated on the St. Charles River at Vineland, Colorado (USGS 07108900) (at the current location since 1978) and the Huerfano River near Boone, Colorado (USGS 07116500) (discontinuously since 1922). The discharge from Salt Creek is also gaged, but primarily consists of return flows. Missing tributary inflows from the St. Charles River and the Huerfano River were estimated using a separate rainfall-runoff model, but since 1995, daily gaged streamflow records are used for those stations.

1.2.3.1.2. *Ungaged Tributary Areas*

Ungaged tributary areas (including the St. Charles and Huerfano Rivers) amount to 15,272 square miles, although they contribute relatively small amounts to the water supply available for diversion in the H-I Model Domain at most times. Inflows to the Arkansas River from the ungaged tributary areas in the H-I Model Domain are estimated using a rainfall-runoff model, which predicts annual runoff values for the ungaged tributary basins. The annual values for the ten ungaged tributary basins estimated by the rainfall-runoff model are based on precipitation and area. See Figure 4: see also Section 3.3.2.1. below and Attachment 6.4. Monthly values are based on the averages for gaged tributaries and are input into the H-I Model as monthly values. The H-I Model converts the monthly values to average daily values by dividing the monthly values by the number of days in the month.

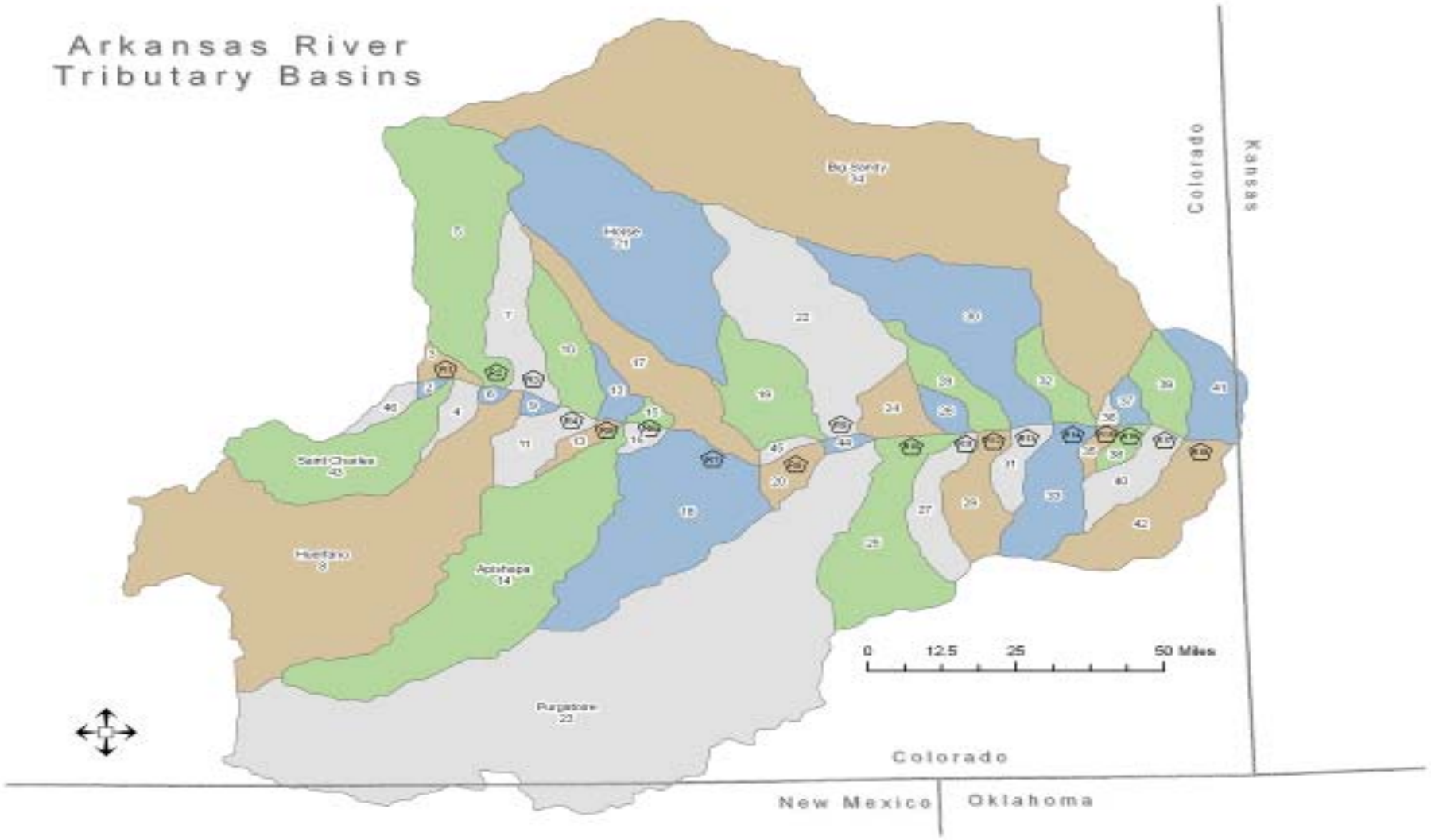


Figure 4. Areas Tributary to H-I Model Domain (for larger scale, see Attachment 6.4.)

1.2.3.2. Transmountain Waters

The Arkansas River Compact apportions the "waters of the Arkansas River," a term defined in Article III of the Compact, which does not include waters brought into the Arkansas River Basin from other river basins. There are nine structures that bring imported or "transmountain" waters into the Arkansas River Basin in Colorado from other river basins: 1) the Hoosier Pass Tunnel, 2) the Columbine Ditch, 3) the Ewing Ditch, 4) the Wurtz Ditch, 5) the Homestake Tunnel, 6) the Charles H. Boustead Tunnel, 7) the Busk-Ivanhoe Tunnel, 8) the Twin Lakes Tunnel and 9) the Larkspur Ditch. Records of deliveries of transmountain water to users in the H-I Model Domain are maintained by the Colorado Division of Water Resources, and transmountain deliveries are an input to the H-I Model. Transmountain deliveries to users in the H-I Model and other transmountain water introduced into the modeled area are included only in the Historical run of the H-I Model. See Section 1.1 above describing the Historical and Compact runs of the H-I Model.

1.3. *Institutional Framework*

The H-I Model incorporates the legal and administrative rules that govern diversion and storage of water by Colorado users and the operation of John Martin Reservoir. These rules include the Colorado doctrine of prior appropriation, which applies to diversions of surface water and tributary groundwater and is administered based on decrees entered by the courts of Colorado and rules and regulations adopted by the Colorado State Engineer. The legal and administrative rules incorporated in the H-I Model also include the Arkansas River Compact and resolutions of the Arkansas River Compact Administration (ARCA) that govern the operation of John Martin Reservoir. Modifications to represent changes to Colorado water rights or other institutional features that are represented in the H-I Model are described later in this section under the heading Institutional Variations (Section 1.4).

1.3.1. Reports of the Special Master and U.S. Supreme Court decisions

The U.S. Supreme Court and its Special Master, Arthur L. Littleworth, have decided many issues regarding the use of the H-I Model. These decisions can be found in the First, Second, Third, Fourth and Fifth Reports of the Special Master (including appendices to the Reports) and the decisions of the U.S. Supreme Court.

1.3.2. Colorado Priority System

A water right in Colorado is a right to use, in accordance with its priority, a certain portion of the water of the state by reason of appropriation. Appropriation is the application of a specified portion of the waters of the state to beneficial use. A water right in Colorado arises by application of water to beneficial use, but is confirmed by a decree, which determines the amount and priority of the water right for the purposes of administration by state water officials. The appropriation date of each water right generally establishes the "rank" or priority of the right, the first right (the senior right) having priority over those rights that are later in time (junior rights). Decrees for diversions for direct use are approved as a rate in cubic feet per second; decrees for storage rights are approved as a volume in acre-feet. Water rights are administered by the State Engineer, division engineers

and water commissioners based on the priority dates in accordance with the decrees of the Colorado courts and applicable laws, including interstate compacts. The list of surface water rights simulated in the H-I Model, including the amount and appropriation date of each right, is shown in Attachment 6.3. Each surface water right simulated in the H-I Model is assigned to a user and a specific reach in the H-I Model. The user and reach assignments are also shown in Attachment 6.3.

Maps showing irrigated lands in the service areas of the users represented in the H-I Model are included in Attachment 6.2. The acreages irrigated in each user area for the years 1950-1985 were determined by Spronk Water Engineers based on aerial photographs taken in the mid-1950s and 1980. The H-I Model uses the first acreage for users for 1950-1968 and the second acreage for 1969-1985; a third acreage was added for 1986-1994 for selected canals. Since 1995, updates to the H-I Model have been made through annual update files, and modifications to the irrigated acreage for users can be made each year. See Attachment 6.10.

1.3.3. Amended Rules and Regulations Governing the Diversion and Use of Tributary Ground Water in the Arkansas River Basin, Colorado

The Colorado State Engineer adopted "Amended Rules and Regulations Governing the Diversion and

Use of Tributary Ground Water in the Arkansas River Basin, Colorado," which were approved by the Colorado Water Court effective June 1, 1996 (Colorado Use Rules). The Colorado Use Rules are contained in Appendix J.1 of this Decree. The Colorado Use Rules prohibit groundwater diversions within the scope of the Rules unless out-of-priority depletions to senior surface water rights in Colorado and depletions to Usable Stateline Flow caused by such diversions are replaced in accordance with plans approved by the Colorado State Engineer pursuant to those Rules. The Colorado Use Rules also provide that unit response functions be developed for wells diverting from the valley fill and surficial aquifers along the Arkansas River between Pueblo and the Stateline. In general, presumptive depletion percentages are utilized with unit response functions to determine out-of-priority depletions to senior surface rights in Colorado and to estimate depletions to Usable Stateline Flow. The Colorado Use Rules provide that the H-I Model shall be used to determine the depletions to Usable Stateline Flow and require well users subject to the Colorado Use Rules to replace all depletions to Usable Stateline Flow if not fully replaced based on plans approved under the Colorado Use Rules. Groundwater pumping values in Colorado are determined based on the Colorado Measurement Rules using totalizing flow meters or electrical power records and power conversion coefficients. The Colorado Measurement Rules are contained in Appendix I.1 of this Decree.

1.3.4. The Arkansas River Compact

The Arkansas River Compact (Compact) was signed by commissioners for Kansas and Colorado and a representative of the United States on December 14, 1948. The Compact was ratified by the legislatures of Kansas and Colorado, was consented to by the Congress of the United States, and became effective in 1949. The major purposes of the Compact are "to settle existing disputes and remove causes of future controversy" concerning waters of the Arkansas River and their control, conservation and utilization, and "to equitably divide and apportion between the States of Colorado and Kansas the waters of the Arkansas River and their utilization as well as the benefits arising from" John Martin Reservoir. The Compact provides for storage of water entering John Martin Reservoir and provides that Colorado and Kansas can make demands for releases of river flow and stored water at times and up to maximum rates specified in the Compact. The Compact provides that when there is water in the conservation pool, the water users upstream from John Martin Reservoir shall not be affected by calls from the decrees in Colorado Water District 67. The ditches of Colorado Water District 67 are those ditches and canals that divert water from the Arkansas River or its tributaries downstream from John Martin Dam in Colorado.

1.3.5. 1980 Operating Plan

On April 24, 1980, the ARCA adopted a Resolution Concerning an Operating Plan for John Martin Reservoir (1980 Operating Plan), which established accounts in John Martin Reservoir allowing water stored in conservation storage to be transferred into accounts (Section II accounts) for Kansas and the ditches of Colorado Water District 67. It was amended May 10, 1984 and December 11, 1984. The 1980 Operating Plan also established additional accounts (Section III accounts) for three Colorado canal companies in the reservoir. The 1980 Operating Plan allows Kansas and the Colorado ditches to demand the release of water stored in their respective accounts at any time and at whatever rate they desire. The H-I Model simulates the storage of water in John Martin Reservoir and releases from the Section II and the Amity Section III account under the Compact and the 1980 Operating Plan. The 1980 Operating plan may be terminated by either State. A permanent pool, not to exceed a maximum size of 15,000 acre-feet, was established in 1976. The permanent pool is not simulated in the H-I Model.

1.3.6. The Winter Water Storage Program

The Winter Water Storage Program (WWSP) involves the storage of "native" waters of the Arkansas River in Pueblo Reservoir and off-channel reservoirs during non-crop growing months (November 15

through the following March 14). "Native" waters are "waters of the Arkansas River" as defined in the Compact and exclude "waters brought into the Arkansas River Basin from other river basins." The WWSP operates in accordance with a decree entered by the Colorado Water Court. The H-I Model predicts winter diversions prior to the initiation of the WWSP in 1976 (and in 1978 when the WWSP did not operate) and simulates diversions under the WWSP within the H-I Model Domain since that time. Because Pueblo Reservoir is not simulated in the H-I Model, WWSP deliveries from Pueblo Reservoir are included as deliveries to specific users in the H-I Model.

1.3.7. Resolution Concerning An Offset Account in John Martin Reservoir for Colorado Pumping

On March 17, 1997, the ARCA and the representative for Chief of Engineers for the U.S. Army Corps of Engineers jointly adopted the Resolution Concerning An Offset Account in John Martin Reservoir for Colorado Pumping (Offset Account Resolution). It has been amended twice by resolution of the ARCA on March 30, 1998. The Offset Account Resolution, as amended, is contained in Appendix L of this Decree. The Offset Account is a separate storage account in John Martin Reservoir. In accordance with the Resolution, water may be delivered to the Offset Account by Colorado well users to offset depletions to Usable Stateline Flow caused by post-compact well pumping

in Colorado. Water delivered to the Offset Account may be released or transferred in accordance with the Resolution. Colorado receives credit for the delivery of water from the Offset Account to the Stateline as a replacement of depletions to Usable Stateline Flow computed by the H-I Model. Credit for delivery of water released from the Offset Account on Kansas' demand and evaporation from water stored in the Kansas Consumable Subaccount of the Offset Account is computed outside the H-I Model in accordance with the Offset Account Crediting Agreement, which is Appendix F.2 of this Decree. Therefore, water delivered to the Offset Account is removed from the H-I Model; however, return flows and transit losses on releases of water from the Offset Account are input into the H-I Model as a "special waters" in accordance with the Crediting Agreement. The Offset Account Resolution may be terminated by either State, except as provided in Appendix A.4 of this Decree.

1.4. *Institutional Variations*

To determine whether post-compact well pumping in Colorado and replacement plans implemented under the Colorado Use Rules have resulted in depletions or accretions to Stateline flows, two runs of the H-I Model are made, the Historical run and the Compact run. The Historical run is made by setting two switches, JPUMP and JTM, to 1. The Compact run is made by setting the two switches to 0. When the switch JPUMP is set to 1, the H-I Model uses the monthly historical pumping for each user. When the

switch JTM is set to 1, the H-I Model uses the historical transmountain deliveries to users. When the switch JPUMP is set to 0, the H-I Model uses the monthly pre-compact pumping allowance for each user. When the switch JTM is set to 0, transmountain deliveries are removed. Because some irrigation rights in Colorado have been changed to municipal use or because of other changes that affect the operations of some users, some variations in the institutional conditions simulated in the H-I Model are necessary. These variations are described below:

1.4.1. Booth-Orchard Ditch

The point of diversion and the use of the water rights decreed to the Booth-Orchard Ditch were changed in 1972, and these water rights are now diverted for municipal use at points of diversion upstream of the H-I Model Domain. The Booth-Orchard Ditch is therefore not allowed to divert water from the Arkansas River after 1972 in both (Historical and Compact) runs of the H-I Model. Some well pumping for irrigation use continued after 1972 in the old Booth-Orchard Ditch service area, and this pumping is included in the H-I Model.

1.4.2. Excelsior Ditch

Surface diversions by the Excelsior Ditch were discontinued in 1989 for a period of 11 years, until 2000. In 1999, some transmountain water was delivered to the ditch. The water rights decreed to the

Excelsior Ditch have been used as a Replacement source since then. The ditch capacity of the Excelsior Ditch is set to 0 during 1989 through 1999 in the Historical run. The ditch capacity is restored in the Compact run. After 2000, portions of the water right are delivered to the river through an augmentation station or to a recharge site at the end of the ditch. These operations are reflected in inputs to the H-I Model. See Section 3.2.1.22.

1.4.3. Colorado Canal

The majority of the shares in the Colorado Canal Company, which owns the water right decreed to the Colorado Canal, and majority of the shares in the Lake Henry Reservoir Company and the Lake Meredith Reservoir Company, which own the water storage rights for Lake Henry and Lake Meredith (which are also diverted at the Colorado Canal), have been changed to municipal use. The water rights continue to be diverted at the Colorado Canal headgate and the consumable portion of the yield of shares changed to non-irrigation purposes is stored in Lake Henry or Lake Meredith for subsequent use by exchange or direct release to the river, the Holbrook Canal, or the Fort Lyon Storage Canal. Some of the lands were dried up and others continue to be irrigated with surface water and wells.

The water rights decreed for diversion at the Colorado Canal are simulated in both runs of the H-I Model as though the water rights continue to be used

for irrigation because the terms and conditions imposed in the decrees changing shares to non-irrigation purposes were intended to maintain historical return flows, and the use and administration of the changed shares is assumed to result in the same effect on the river as if irrigation with the shares had continued. However, the acreage receiving supplemental irrigation pumping was reduced in 1986, 1988 and 1992 to reflect the gradual dry-up of lands from shares changed to non-irrigation purposes. Releases of consumable water from Lake Meredith for exchange or other uses are accounted for using input data sets described later in this narrative.

1.4.4. Rocky Ford Ditch

Most of the shares in the Rocky Ford Ditch Company have been changed to municipal use. Most of the Rocky Ford Ditch water rights are now diverted at alternate points of diversion or storage upstream from the H-I Model Domain. The changes are represented by reducing the amount of the water rights and the irrigated area in both H-I Model runs starting in 1993.

1.4.5. Las Animas Consolidated Canal

The water right decreed to the Las Animas Town Ditch was historically diverted at the headgate of the Las Animas Consolidated Canal. The Las Animas Town Ditch water right was purchased by the Rocky Ford Highline Canal Company, and the point of

diversion was changed to the Rocky Ford Highline Canal. To account for this change, the point of diversion of the Las Animas Town Ditch water right is changed from the Las Animas Consolidated Canal (User 13) to the Rocky Ford Highline Ditch (User 6) starting in 1971.

1.4.6. Fort Bent Canal

The Lower Arkansas Water Management Association (LAWMA) owns or controls shares in the Fort Bent Ditch Company that are used for Replacement. LAWMA diverts water available under the shares it owns or controls at the Fort Bent Ditch river headgate and returns water to the Arkansas River through an augmentation station (turnout). The use of these shares for Replacement is represented in the H-I Model by a spill factor in the Historical run that returns a portion of the water diverted at the Fort Bent Ditch based generally on an annual ratio that is determined from the measured releases at the augmentation station divided by the total annual diversions. The number of shares used for replacement are used to determine the pro rata amount of the diversion available for replacement use. The acreage irrigated by the Fort Bent Ditch in the Historical run excludes the acreage that is not irrigated by LAWMA's shares (dry-up acreage). The spill factor does not operate in the Compact run and the dry-up acreage is added to the acreage irrigated by the Fort Bent Ditch. The spill factor and dry-up acreage are added starting in 1996.

1.4.7. Lamar/Manvel Canal

LAWMA owns or controls shares in the Lamar Canal Company and the Manvel Canal Company that are used for Replacement. Except as noted below, the use of these shares is represented in the H-I Model in the same manner as the Fort Bent Ditch Company shares owned or controlled by LAWMA. The spill factor and dry-up acreage are added starting in 1996.

Manvel Section II account water is transferred to a separate LAWMA account in John Martin Reservoir in the H-I Model starting in 1996. This account was created in the H-I Model to facilitate accounting for the use of water in Section II accounts used by LAWMA in its replacement plans. Transfers of consumable water from the LAWMA account to the Offset Account are removed from the Historical run because credits for releases from the Offset Account are determined outside the H-I Model. Other releases are represented in the H-I Model as "special waters" in the Historical run. See Section 3.3.4.

1.4.8. X-Y Graham Ditch

LAWMA now owns 67 cubic feet per second (cfs) of the 69 cfs of the X-Y water right and all of the X-Y Graham Section II account and uses water available to its portion of the X-Y water right and the X-Y Graham Section II account water for Replacement. The water right decreed to the Graham Ditch was also diverted through the X-Y Canal. The point of diversion of 59.43 cfs of the 61 cfs decreed to the

Graham Ditch was changed to wells in decrees entered in 1977. This change is represented by increasing the historical diversions of the X-Y Canal that are used to calibrate want factors in the H-I Model beginning in 1977. The headgate of the X-Y Canal was plugged after LAWMA purchased its interest in the X-Y water right and the X-Y Graham Section II storage account. The use of LAWMA's interest in the X-Y water right as replacement water is represented in the H-I Model by a spill factor that returns all water diverted by the X-Y Canal water right to the Arkansas River in the Historical run. The post-compact pumping for the X-Y Graham is increased in the H-I Model by 0.83 cfs to account for the continued irrigation of 180 acres using drain flow by the remaining interests of the X-Y water right. The 180 acres irrigated with the outstanding interest is included in the irrigated area. The X-Y Graham Section II account water is transferred to the LAWMA account in John Martin Reservoir in the H-I Model starting in 1996. Transfers of consumable water from the LAWMA account to the Offset Account are removed from the Historical run. Other releases are represented in the H-I Model as "special waters" in the Historical run. The acreage irrigated in the X-Y Graham service area in the Historical run is reduced for the lands that have been dried up. In the Compact run, the spill factor is not operated and the dry-up acreage is irrigated by the X-Y and Graham water rights and the X-Y Graham Section II account.

1.4.9. Sisson-Stubbs Ditch

Two water rights were historically diverted at the Sisson-Stubbs Ditch, a water right for 18.0 cfs decreed to the Sisson Ditch and a water right for 7.2 cfs decreed to the Stubbs Ditch. The Sisson-Stubbs Ditch received a single percentage for releases of stored water from John Martin Reservoir under distribution agreements among the water users in Colorado Water District 67 under the Compact and in the 1980 Operating Plan. The Sisson and Stubbs operations were represented as a single user in the H-I Model. Diversions by the ditch were discontinued by 1974. LAWMA purchased the Stubbs water right and a portion of the Sisson-Stubbs Section II account in 1989 and has used them for Replacement. The Sisson water right was changed to wells. The ditch capacity of the Sisson-Stubbs Ditch is set to 0 in the Historical run of the H-I Model beginning in 1974 so that no surface water can be delivered to the Sisson-Stubbs lands. The ditch capacity is restored in the Compact run, thereby allowing the H-I Model to calculate the credit from the use of the Stubbs water right for Replacement and the use of wells as new points of diversion for the Sisson water right.

To represent the Sisson-Stubbs water rights in the H-I Model, the States entered into an agreement contained in Appendix B.5 of this Decree. The agreement specifies, among other things, the following: (1) the method and data to derive the calibrated want factors that are used to predict diversions in the H-I Model; (2) the acreage in the Compact run will be set to 480

acres; (3) after 1996, the acreage will be based on 480 acres; 240 acres will be shown as dried-up under the Stubbs portion of the ditch, so long as these acres remain not irrigated from any source or will be treated as sole source acreage if irrigated with groundwater; (acreages in the Historical run for 1950-1996 will be left at the values that are used in previous data sets); (4) water in the Sisson-Stubbs Section II account will be transferred to the LAWMA account starting in 1996; and (5) return flows from Sisson-Stubbs Section II account water delivered to the Offset Account will be modeled in accordance with the provisions in the Offset Account Crediting Agreement (Appendix F.2 of this Decree).

1.5. *Major H-I Model Components*

The H-I Model is a computer program written in FORTRAN. Conceptually, the H-I Model has five "modules": a supply module, an administrative module, a land module, a ground-water module and a river module. The H-I Model program consists of a short MAIN part that reads in data from input files and calls six subroutines, named SUPPLY, GET, LAND, GWFLOW, ROUTE and BUDGET. The subroutines are described in the following sections. Some logical flow charts are included in those sections. A more comprehensive set of logical flow charts is included in the DVD. Although some changes have been made to the program since then, the flow charts are still very useful in understanding the H-I Model program.

The water supply available for allocation is compiled throughout the H-I Model Domain on monthly time steps in the SUPPLY subroutine, and then converted to daily values to predict diversions. The supply includes river inflow at Pueblo (as adjusted at the Pueblo Composite Gage), tributary inflows, and precipitation. Diversions of river water for irrigation use are calculated in the GET subroutine based on the priority and the amount of the water rights and irrigation demands for the land served by the users represented in the H-I Model. Diversions of river water for storage are based on the priority of the water storage rights, the available capacity in the reservoirs and, for off-channel reservoirs, the available capacity in the canals used to fill the reservoirs. The irrigation water supply is simulated by adding computed diversions from the river, releases from storage, effective precipitation and pumped groundwater, and deducting conveyance and farm losses. The available water supply and crop demand (potential evapotranspiration) are used to determine the crop consumptive use and irrigation return flows in the LAND subroutine. Well pumping for irrigation is an input to the H-I Model and is added to the irrigation supply for lands that are irrigated by groundwater in each user area. Depletions and accretions to the river from pumping and irrigation return flows are computed in the GWFLOW subroutine. The streamflow in each river reach is computed in the ROUTE subroutine. H-I Model results and overall mass balance checks are developed in the BUDGET subroutine.

Input data and parameters for the H-I Model are read in from a series of data files, described in more detail below. Time variant data, such as streamflow, precipitation and irrigation pumping, are input through files that were prepared for the original H-I Model and updated through 1994. H-I Model updates for years starting in 1995 are accomplished through a single data file, UPDATE.DAT, which is constructed for each year updated.

In general, the natural flow of the Arkansas River (including tributary inflows, but excluding transmountain, WWSP deliveries and other reservoir deliveries to specific users) is allocated in order of the priorities of the water rights simulated in the H-I Model to meet the irrigation demands of the users. Any unmet demand after exhausting the available natural flow is met by releases from off-channel storage, if available to a user, or from John Martin Reservoir, if available to a user. The solution process is iterative to allocate available streamflow, including return flows. Precipitation, transmountain deliveries, WWSP deliveries from Pueblo Reservoir and irrigation pumping are input and considered fixed in the H-I Model, except that transmountain deliveries are removed in the Compact run and pumping in the Compact run is limited to the pre-compact pumping allowance.

1.5.1. SUPPLY Subroutine

The SUPPLY subroutine compiles the river and tributary inflow data and precipitation. This subroutine compiles the H-I Model inflows and allocates them to stream reaches. River evaporation and phreatophyte consumption are deducted from streamflow. Precipitation is assigned to users.

The SUPPLY subroutine reads in four files, named SUPPLY0.DAT, PRCP.DAT, TREES.DAT and RESR.DAT, SUPPLY0.DAT contains monthly data for the river inflow at Pueblo (as adjusted at the Pueblo Composite Gage) and tributary inflows for 45 tributary subbasins. SUPPLY0.DAT includes 46 "tributary stations." The first "tributary station" is the monthly streamflow of the Arkansas River at the Pueblo Composite Gage, which includes inflows from Fountain Creek, but does not include inflows from Salt Creek. The monthly discharges from Salt Creek are included as tributary station No. 46 in SUPPLY0.DAT, which are assigned to Reach 1 of the H-I Model. The location of the tributary subbasins is shown in Figure 4. TREES.DAT contains data for phreatophyte consumption along the river. The phreatophyte consumption for the period 1950-1985 was based on estimates prepared during the course of the H-I Model development. Phreatophyte consumption is the same in the Historical and Compact runs of the H-I Model. RESR.DAT contains data to calculate river surface evaporation.

To simulate daily flows of the Arkansas River, the H-I Model uses the daily flows of the Arkansas River above Pueblo (USGS 07099400) and the daily flows of the Purgatoire River near Las Animas (USGS 07218500) to adjust certain monthly inflows to the H-I Model. The monthly flow of the Arkansas River at the Pueblo Composite Gage is distributed to a daily value based on the pattern of the daily gaged streamflow of the Arkansas River above Pueblo (USGS 07099400). The data used to create the Pueblo Composite Gage are described in Data Sets 5 and 6 for the annual update files. Because some monthly data is used to create the Pueblo Composite Gage, the H-I Model adjusts the monthly values based on the pattern of the daily flows of the Arkansas River above Pueblo. The inflow to the Arkansas River from the Purgatoire River includes a small component of monthly inflows from tributary areas below the streamflow gage on the Purgatoire River near Las Animas. The monthly inflow to Reach 10 in the H-I Model (which includes the monthly flows of the Purgatoire River near Las Animas, which are included as tributary station No. 23 in SUPPLY0.DAT) is distributed to a daily value based upon the pattern of the daily gaged streamflow of the Purgatoire River near Las Animas (USGS 07218500). Daily inflow data for the Arkansas River above Pueblo (USGS 07099400) and the Purgatoire River near Las Animas (USGS 07218500) are contained in the file QDAY.DAT.

For other tributaries with daily gaged streamflow records, the H-I Model uses daily records published by the USGS beginning in 1995. These are the Huerfano River (USGS 07116500) and the Apishapa River (USGS 07119500). Prior to 1995, the H-I Model used monthly flows for the Huerfano and Apishapa River, which are included as Tributary Station Nos. 8 (Huerfano) and 14 (Apishapa) in SUPPLY0.DAT. For ungaged tributaries, the H-I Model uses monthly values derived from a rainfall-runoff model. The procedure to estimate ungaged tributary inflow is described in more detail in Section 3.3.2.1. Monthly inflows from ungaged tributaries are converted to average daily values by dividing the monthly inflow by the number of days in the month.

1.5.2. GET Subroutine

The GET subroutine simulates the daily allocation of natural river flow and the release of stored water to meet irrigation demands generally in accordance with the Colorado prior appropriation system, the Compact and the 1980 Operating Plan for John Martin Reservoir. This subroutine allocates the natural river flow in each reach to Colorado water rights in order of their priorities to the extent water is available to meet the users' demands for irrigation water and there is canal capacity available to divert water, and then determines the reservoir releases needed to meet demands of Colorado users and demands by Kansas. See Figure 5 (based on Kan. Exh.

543, River Diversions and Reservoir Releases). Not all users in the H-I Model have reservoir water available to meet their demands. In general, the assumption made in the H-I Model is that users who have off-channel reservoir water available will divert natural river flow to meet their demands before calling for the release of reservoir water. Some users have off-channel reservoirs, and some users receive releases from John Martin Reservoir. The logic used in the H-I Model to simulate the operation of John Martin Reservoir and releases of stored water from 1950-1979 is intended to represent the operation of the reservoir under the Arkansas River Compact and distribution agreements entered into by the ditches of Colorado Water District 67. See Figure 6 (based on Kan. Exh. 544, Operation of John Martin, Arkansas River Compact). The logic used in the H-I Model to simulate the operation of John Martin Reservoir and releases of stored water beginning in 1980 is intended to represent the 1980 Operating Plan. See Figure 7 (based on Kan. Exh. 545, Operation of John Martin, 1980 Resolution).

To predict diversions, the H-I Model uses a list of 89 water rights, which includes the amount and the appropriation date of each water right. The water rights are assigned to the reaches of the H-I Model based on the location of the ditch where the water rights are diverted. The list of Colorado water rights is included in Attachment 6.4. To predict diversions for irrigation use, the H-I Model uses

monthly estimates of potential evapotranspiration (PET) for each user, which are divided by the number of days in the month to estimate an average daily demand for each user. An estimate of the daily effective rainfall is then subtracted from the daily PET to estimate the daily demand for irrigation water of each user. Daily effective rainfall is determined using the U.S. Bureau of Reclamation method. The H-I Model then multiplies the daily PET, less the daily effective rainfall, times the area irrigated in the user area times a want factor (WTFACT) for each user to predict the amount of water a user would want to divert from the river on a daily basis for irrigation if water is available for diversion. Monthly WTFACTs for each user are adjusted through a calibration process. For some users, diversion reduction factors (DVFACs) are also applied to limit diversions in certain months. Diversion reduction factors were used to calibrate the H-I Model. The values for the diversion reduction factors were derived for the calibration of the Replacement Model (Dec. 1991) and have not been modified as part of the calibration process in subsequent calibrations (See Section 5.2). The water rights that diversion reduction factors are applied to, the values for the diversion reduction factors and the months the diversion reduction factors are applied are shown below:

Table 3. Diversion Reduction Factors

Structure	Water Right	DVFAC	Months
Colorado Canal	6/9/1890	0.75	May – Sept.
Lake Henry	12/31/1891	0.75	May – Sept.
Lake Meredith	3/9/1898	0.75	May – Sept.
Lake Henry	6/15/1909	0.75	May – Sept.
Ft Lyon Canal	3/1/1887	0.85	May – Aug.
	8/31/1893	0.85	May – Aug.
Great Plains Res	8/1/1896	0.75	April – Oct.
Amity Canal	2/21/1887	0.75	June – Aug.
	4/1/1893	0.75	June – Aug.

Canal capacities were also reduced to calibrate the H-I Model.

To predict diversions during the winter storage months (November through March), the H-I Model uses a factor (WTADD) for each user, which represents the daily amount of water in acre-feet that each user would want to divert from the river if water is available for diversion. Each user has a set of monthly WTADD factors that are derived through a calibration process to predict the average diversions by each user in the Historical run. For the months of April and October, the H-I Model has both WTFACTs and WTADDs. The higher of the diversions predicted using the WTFACTs and WTADDs is used for predicted diversions in those months. Values of the WTFACTs and WTADDs are contained in the file WTFACT.DAT.

In general, the logic used in the GET subroutine to predict daily diversions is that a user is allowed to divert under a water right the lesser of: (1) the amount of the water right; (2) the amount of natural river flow available for diversion; (3) the canal capacity (or the remaining canal capacity if other water has been diverted by or delivered to the user on that day); and (4) the daily crop demand for irrigation water (WANT). The WANT is determined using the following equation:

Equation (1): WANT = WTADD + WTFACT * AREA * (PETDAY-PPTEFF),

where WTADD is the factor used primarily to determine the winter WANT, WTFACT is the factor used primarily to determine the summer WANT, AREA is the irrigated area, and (PETDAY-PPTEFF) is the daily crop demand for irrigation water. The DVFAC is applied to certain users after the WANT and available supply have been used to compute the diversion amount. See Figure 5.

Releases from John Martin Reservoir for water users in Colorado Water District 67 and Kansas are determined by the H-I Model to meet the demands of the Colorado Water District 67 users and Kansas in accordance with the provisions of the Arkansas River Compact or the 1980 Operating Plan.

Releases from John Martin Reservoir for Colorado prior to the adoption of the 1980 Operating Plan are made in the H-I Model if the available supply is not sufficient to satisfy the demands of the Colorado

Water District 67 users for irrigation water. Releases are made to equal the unsatisfied demands plus any groundwater deficits in the reaches between John Martin Dam and the Stateline, up to the maximum release rate that Colorado may demand from the reservoir.

Releases from John Martin Reservoir for Kansas prior to the adoption of the 1980 Operating Plan are made in the H-I Model if Colorado Water District 67 users are demanding a release from the reservoir and the Stateline flow calculated by the H-I Model without a release is below a monthly threshold amount. The monthly Kansas threshold demands (1950-79) are contained in the file RIGHT.DAT. The monthly Kansas threshold demands are included in Attachment 6.6. If both conditions are satisfied and water is available in conservation storage, the H-I Model will compute a release necessary to provide the maximum flow rate that Kansas may demand under the Compact at the Stateline, up to a maximum Kansas call for the month. See Figure 6. The monthly maximum Stateline calls are contained in the file RIGHT.DAT and are included in Attachment 6.6. The monthly maximum Stateline calls were based on a review of historical Stateline flows during months when Kansas demanded a release of water from John Martin Reservoir.

Releases from John Martin Reservoir for Colorado Water District 67 users under the 1980 Operating Plan are made from the Colorado Water District 67 users Section II accounts when diversions of

natural river flow are not sufficient to satisfy a user's demand for irrigation water. Releases from John Martin Reservoir for Kansas under the 1980 Operating Plan are computed to provide enough water to satisfy a monthly Stateline demand or call by Kansas if water is available in the Kansas Section II account. The monthly Kansas calls are contained in the file RIGHT.DAT and were derived through calibration. The monthly Kansas calls beginning in 1980 are included in Attachment 6.7. The amount charged to the Kansas Section II account is the full amount of the demand, as provided for in the 1980 Operating Plan.

The GET subroutine reads in data from eight data files: RIGHT.DAT, TMOUNT.DAT, RESR.DAT, QDAY.DAT, WINTER.DAT, PUMP.DAT, PUMP48.DAT and WTFACT.DAT. The GET subroutine calculates diversions based on a daily time step. The data files read in by the GET subroutine are described below.

RIGHT.DAT contains the list of the 89 Colorado water rights simulated in the H-I Model (see Attachment 6.3.), the user that each water right is assigned to, the river reach from which each water right is diverted, the amount of each water right, the appropriation date of each water right, whether a diversion reduction factor is applied to diversions under the water right, and the maximum canal capacity of each ditch represented in the H-I Model. RIGHT.DAT also contains information on the number of water rights diverted from the river by each user, whether the user receives transmountain deliveries, whether the

user is a participant in the WWSP, whether groundwater is the sole source of supply, and whether groundwater or off-channel reservoir storage is a source of supply. RIGHT.DAT also contains the allocation of conservation storage to the ditches of Colorado Water District 67 prior to and under the 1980 Operating Plan. A summary of information in RIGHT.DAT is included in Attachment 6.8.

RIGHT.DAT also contains reservoir capacities, Kansas threshold demands (1950-79), maximum Kansas calls, Kansas historical calls for releases (1980-1994), the order of WWSP deliveries to users, information to compute Fort Lyon Canal direct-flow diversions during the WWSP, and Lamar Power Plant discharges. A summary of parameters for reservoirs in RIGHT.DAT is included in Attachment 6.9. The reservoir capacity for John Martin Reservoir is reduced periodically in the H-I Model to reflect the reduction in capacity due to siltation. The Great Plains Reservoirs are simulated as a single reservoir; however, the capacity of the reservoir is increased in 1984 to reflect the additional storage capacity that became available in Nee Gronda Reservoir in that year.

TMOUNT.DAT contains monthly transmountain deliveries to nine Colorado users. The transmountain deliveries are subtracted from the monthly flow at the Pueblo Composite Gage because such deliveries are not part of the natural river flow available for diversion under the priority system. TMOUNT.DAT also contains conveyance loss factors used to subtract

transmountain deliveries from the Pueblo Composite Gage, transmountain return flows included in the inflows from Fountain Creek, daily transmountain diversion factors for the Colorado Canal and native water delivered to the Colorado Canal from Twin Lakes Reservoir. For eight of the users who received transmountain deliveries, the monthly deliveries are divided by the number of days in the month in the H-I Model and delivered to the users. However, because the Colorado Canal historically received large deliveries of transmountain water from Twin Lakes Reservoir, which is located outside the H-I Model Domain, the H-I Model uses daily factors to apportion the monthly transmountain deliveries to the Colorado Canal. Also, because not all water delivered to the Colorado Canal from Twin Lakes Reservoir is transmountain water, RIGHT.DAT includes the native water delivered to the Colorado Canal from Twin Lakes Reservoir. This file is used so that only transmountain deliveries are removed in the Compact run.

RESR.DAT contains parameters for calculating evaporation from reservoirs, including monthly evaporation rates and storage-area parameters for reservoirs. The file RESR.DAT also contains data to calculate evaporation from the river surface, which is read in the SUPPLY subroutine.

QDAY.DAT contains the daily streamflow of the Arkansas River above Pueblo and the Purgatoire River near Las Animas.

WINTER.DAT contains monthly WWSP deliveries from Pueblo Reservoir to Colorado users. The WWSP deliveries are subtracted from the Pueblo Composite Gage because such deliveries are not part of the natural river flow available for diversion under the priority system.

PUMP.DAT contains monthly groundwater pumping for Colorado users. This file is used in the Historical run of the H-I Model.

PUMP48.DAT contains monthly groundwater pumping for Colorado users based on the 15,000 acre-foot pre-compact pumping allowance. This file is used in the Compact run of the H-I Model.

WTFACT.DAT contains factors used to compute the demand for irrigation water.

The following three figures contain flow charts of three conditions simulated in the H-I Model. The first figure (Figure 5) illustrates the allocation of the natural river flow prior to the 1980 Operating Plan when there is no water in conservation storage in John Martin Reservoir. In this condition, the natural river flow is allocated for all reaches in the H-I Model according to the priority system, starting with the most senior water right. The H-I Model first calculates each user's daily demand for irrigation water (WANT), then adjusts the demand for transmountain or WWSP deliveries, and then allocates the available natural river flow, including tributary inflow, and return flows, starting with the most senior water right, until all water has been allocated. The H-I

Model begins with the return flows from the previous month, then goes through ten iterations to recalculate return flows and diversions for the current month.

The second figure (Figure 6) illustrates the operation of the river prior to the 1980 Operating Plan when there is water in conservation storage in John Martin Reservoir. In this condition, the natural river flow of the river in the reaches upstream from John Martin Reservoir is allocated according to the priority system, starting with the most senior right in the reaches upstream of John Martin Reservoir. The natural flow of the river entering John Martin Reservoir and water stored in conservation storage is allocated as shown on the flow chart, depending on whether it is the summer or winter storage season and the amount in conservation storage. This logic for the operation of the river and making releases of river flows and conservation storage prior to the 1980 Operating Plan is based on the provisions of Article V of the Arkansas River Compact.

The third figure (Figure 7) illustrates the operation of the river under the 1980 Operating Plan. In this condition, the natural flow of the river in the reaches upstream from John Martin Reservoir is allocated according to the priority system for water rights upstream of John Martin Reservoir. When there is water in conservation storage, inflows to John Martin Reservoir are stored and Colorado Water District 67 users are supplied from the natural flow downstream of the dam and releases from their Section II accounts, and releases are made for Kansas

from the Kansas Section II account to satisfy the Kansas demand.

The Amity Mutual Irrigation Company also has a Section III account in John Martin Reservoir, which is used to store water under its Great Plains Reservoir water storage right. A 35% storage charge is imposed on storage in Section III accounts, which is transferred to a Kansas transit loss account. Excess water is transferred to Kansas and Colorado Section II accounts as set out in the 1980 Operating Plan. The 1980 Operating Plan also provides for the order of spill of the various accounts. The H-I Model first releases water from the Amity Section II account before making releases from the Amity Section III account.

When conservation storage is empty, river inflows are allocated, starting with the most senior right in those reaches, and additional water is released from the accounts as needed for the Colorado Water District 67 users and Kansas. If a Section II account of a Colorado Water District 67 user is empty, that user can place a call for water upstream of John Martin Reservoir. The allocation of natural flow of the river entering John Martin Reservoir, water stored in conservation storage, and water stored in the accounts in John Martin Reservoir is described in more detail shown in the flow charts on the figures.

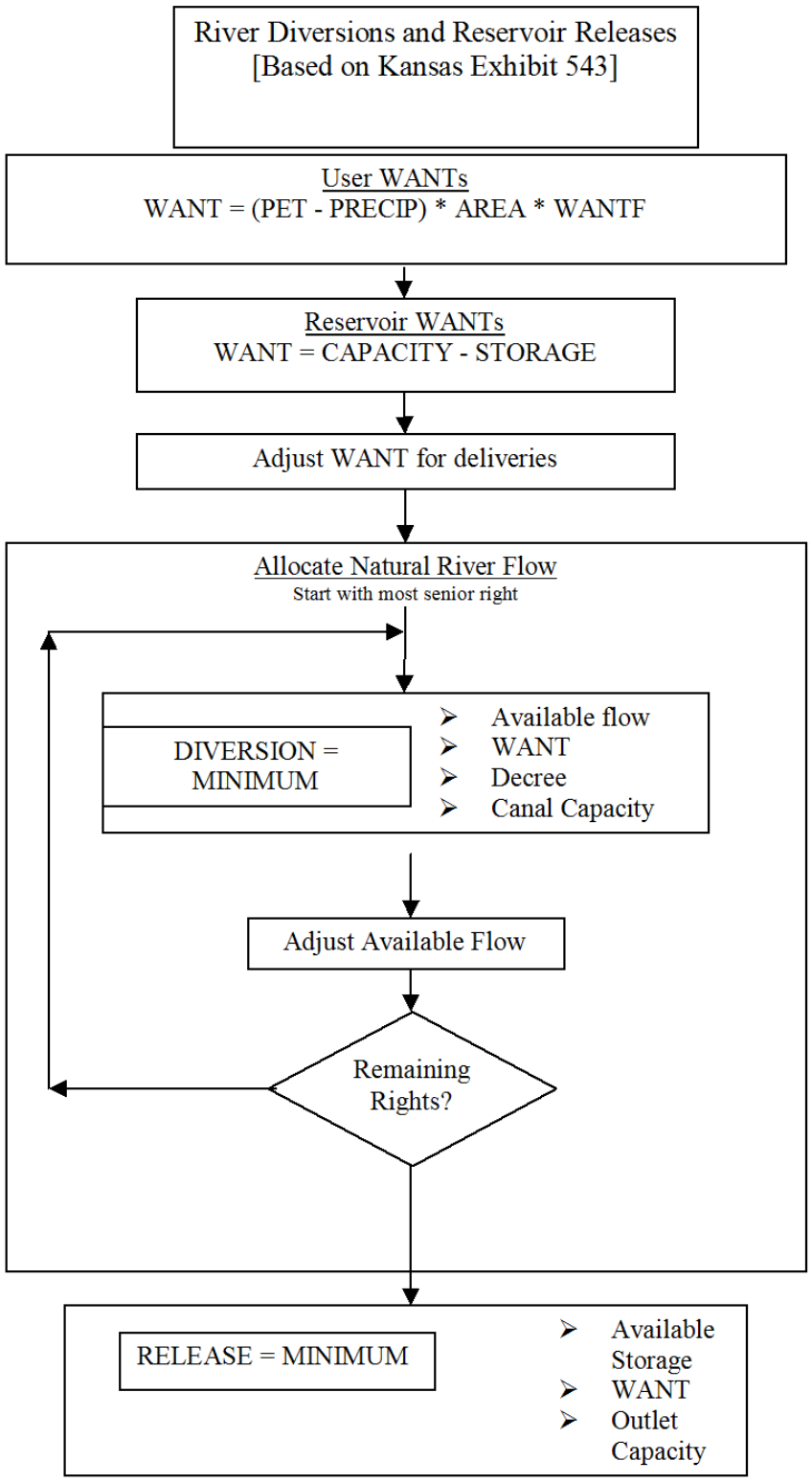


Figure 5. Logical Flow Chart: River Diversions and Reservoir Releases

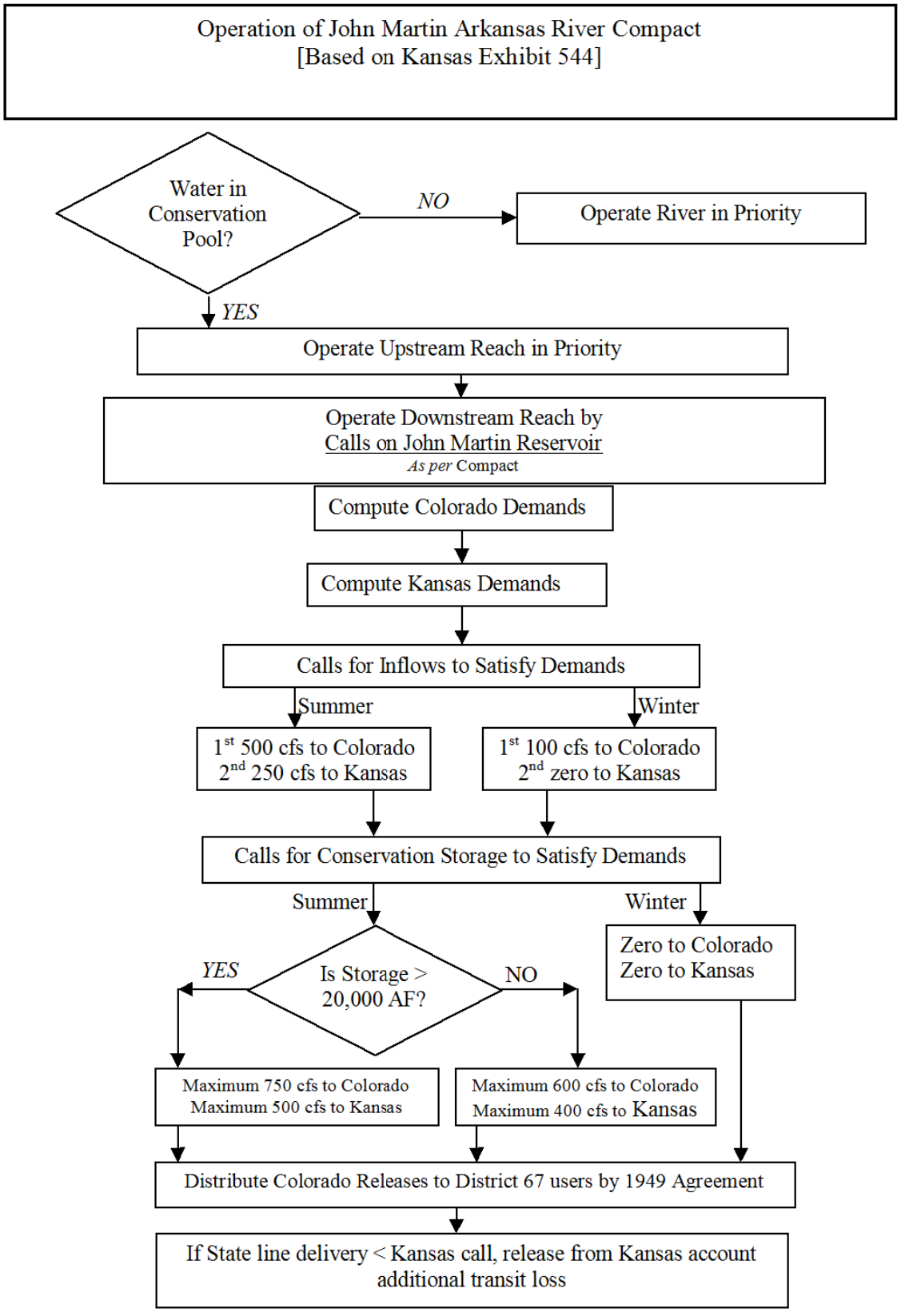

Operation of John Martin Arkansas River Compact
[Based on Kansas Exhibit 544]
Water in Conservation Pool?
NO
Operate River in Priority
YES
Operate Upstream Reach in Priority
Operate Downstream Reach by
Calls on John Martin Reservoir
As per Compact
Compute Colorado Demands
Compute Kansas Demands
Calls for Inflows to Satisfy Demands
Summer
Winter
1st 500 cfs to Colorado
2nd 250 cfs to Kansas
1st 100 cfs to Colorado
2nd zero to Kansas
Calls for Conservation Storage to Satisfy Demands
Summer
Winter
YES
Is Storage > 20,000 AF?
NO
Zero to Colorado
Zero to Kansas
Maximum 750 cfs to Colorado
Maximum 500 cfs to Kansas
Maximum 600 cfs to Colorado
Maximum 400 cfs to Kansas
Distribute Colorado Releases to District 67 users by 1949 Agreement
If State line delivery < Kansas call, release from Kansas account
additional transit loss

Figure 6. Logical Flow Chart: Compact Operation of John Martin Reservoir

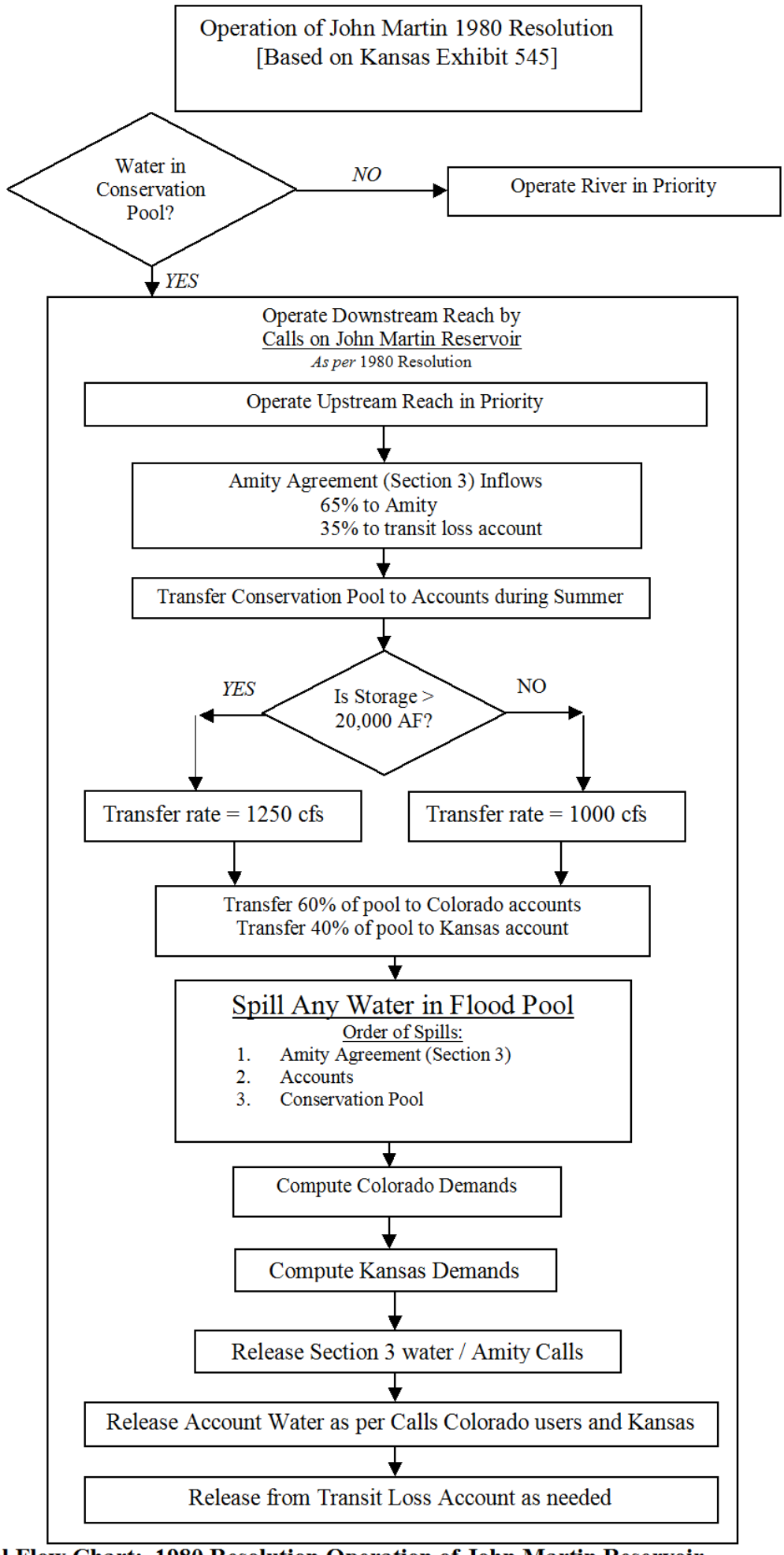

Operation of John Martin 1980 Resolution
[Based on Kansas Exhibit 545]
Water in Conservation Pool?
NO
Operate River in Priority
YES
Operate Downstream Reach by
Calls on John Martin Reservoir
As per 1980 Resolution
Operate Upstream Reach in Priority
Amity Agreement (Section 3) Inflows
65% to Amity
35% to transit loss account
Transfer Conservation Pool to Accounts during Summer
YES
Is Storage > 20,000 AF?
NO
Transfer rate = 1250 cfs
Transfer rate = 1000 cfs
Transfer 60% of pool to Colorado accounts
Transfer 40% of pool to Kansas account
Spill Any Water in Flood Pool
Order of Spills:
1. Amity Agreement (Section 3)
2. Accounts
3. Conservation Pool
Compute Colorado Demands
Compute Kansas Demands
Release Section 3 water / Amity Calls
Release Account Water as per Calls Colorado users and Kansas
Release from Transit Loss Account as needed

Figure 7. Logical Flow Chart: 1980 Resolution Operation of John Martin Reservoir

1.5.3. LAND Subroutine

The LAND subroutine simulates the distribution and consumption of water by the various users on a monthly time step. River diversions (including transmountain deliveries and WWSP deliveries), reservoir releases, precipitation and groundwater pumping are used to calculate canal seepage, lateral losses, precipitation runoff, tailwater, soil moisture storage, deep percolation and crop consumptive use. See Figure 8.

The LAND subroutine reads in data from two data files: LAND.DAT and PET.DAT. LAND.DAT includes, for each user, the irrigated acreage in the user area and the percentage of the area irrigated by surface water only, groundwater only and surface and groundwater. In the update files, the acreage irrigated by surface water only, the acreage irrigated by surface and groundwater, the acreage irrigated by groundwater only, and the acreage removed from irrigation for replacement credit (dry-up acreage) are input separately on an annual basis. LAND.DAT also contains information used to calculate soil moisture storage for each user, including the available water-holding capacity of the soil, the initial soil moisture, referenced to zero wilting point, and the depth of the root zone for each user. LAND.DAT also contains a seepage factor and the length of the canal for computing canal losses, a tailwater factor for each user, and an SEV factor or the percentage of canal and lateral losses and tailwater that is consumed by evaporation

or non-crop evapotranspiration. See Figure 8. Further detail regarding the LAND subroutine is given below.

PET.DAT contains the monthly potential crop evapotranspiration (PET) for each user for the years 1950 through 1994, which is computed independently using the Penman-Monteith equation and crop coefficients to develop adjustment ratios that were applied to PET values computed using the modified Blaney-Criddle method.

After the H-I Model has predicted daily diversions and reservoir releases (if any) for each user for a month, subroutine LAND calculates the amount of water consumed by crop evapotranspiration (consumptive use) and the amount that returns to the river as surface runoff or recharges the groundwater system. In this subroutine, the H-I Model calculates the amount of water diverted from the river or released from storage that is available to the farms, after losses to canal and lateral seepage. Effective precipitation is added to the surface water supply to the farms, and groundwater pumping is added to the water supply available to the farms for acreage irrigated with groundwater. Subroutine LAND calculates the amount of water that returns to the river as surface water runoff and the amount that recharges the groundwater system as canal and lateral losses and deep percolation. The H-I Model makes these calculations for the 23 users for each month simulated in the H-I Model.

Two users in the H-I Model represent Colorado water users who use groundwater as a sole source of supply. For those users, there are no river diversions and the calculations in subroutine LAND are limited to the calculations applicable to precipitation and groundwater pumping. Because some well owners use flood and furrow methods to irrigate and some use center pivot sprinklers, the maximum farm efficiency of these users was determined based on the percentage of the acreage in the user area irrigated with sprinklers.

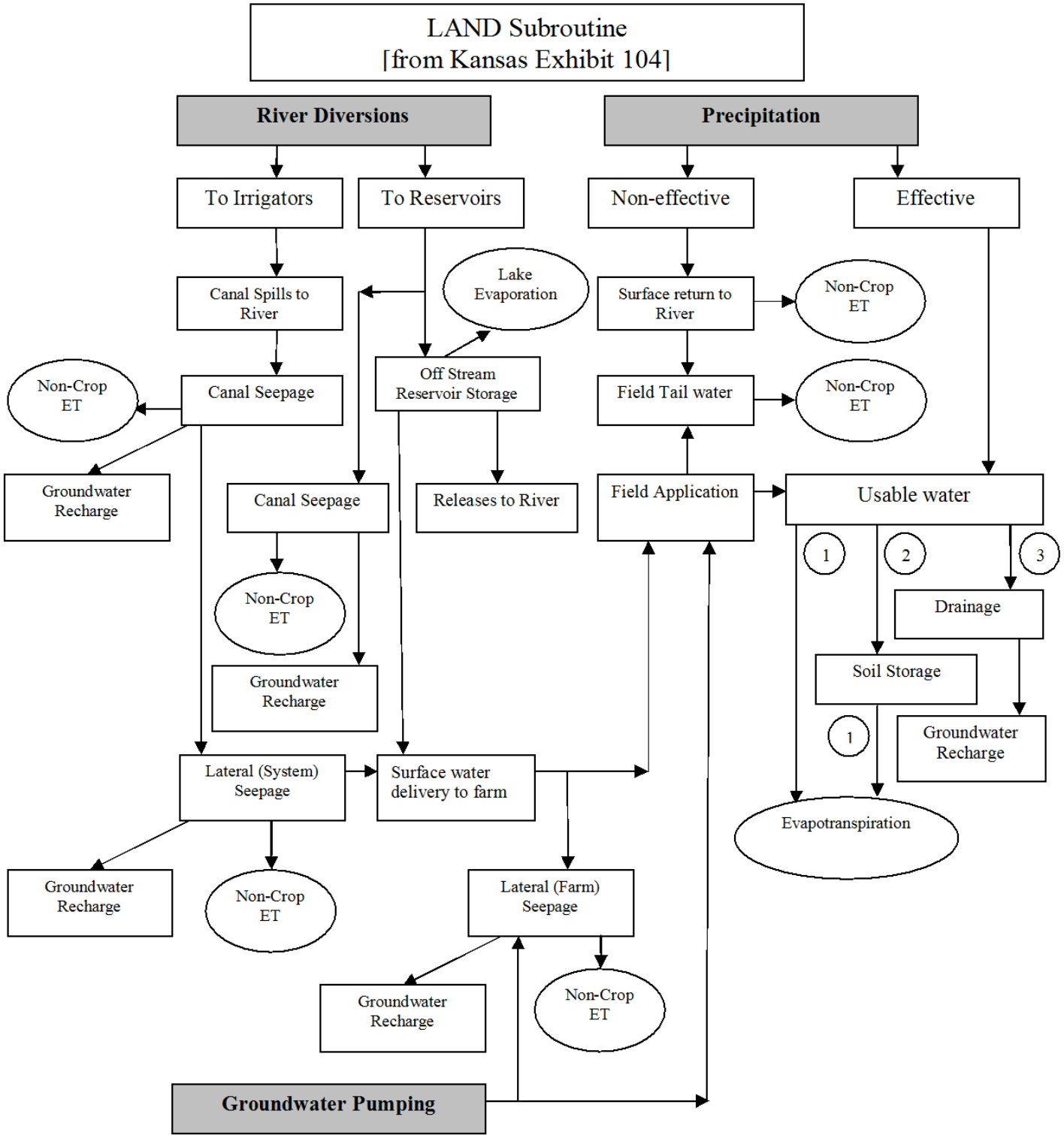


Figure 8. Logical Flow Chart: Land Subroutine

Canal seepage, lateral losses and tailwater runoff are calculated using coefficients in LAND.DAT. Canal seepage was estimated based on the length of the canals. Off-farm lateral losses were estimated as 3.5% of farm headgate deliveries. Effective precipitation and precipitation runoff are calculated using monthly precipitation and the U.S. Bureau of Reclamation methodology for determining effective precipitation. Non-effective precipitation is returned to the river. On-farm losses include on-farm lateral losses, tailwater runoff and deep percolation of field deliveries. In 1996, the H-I Model code was modified to implement a maximum farm irrigation efficiency for each user. This factor defines the maximum amount of irrigation water available to the crop, after farm losses, as a percentage of farm water deliveries. The minimum farm water loss is comprised of on-farm lateral loss, tailwater runoff and initial deep percolation. When water is available in excess of the PET and the minimum farm water loss, it is placed into soil moisture storage in the H-I Model. When the field capacity of the soil moisture storage is exceeded, additional deep percolation is calculated. If the water available to the crop is insufficient to meet the PET, soil moisture is used until soil moisture reaches the wilting point. Canal seepage, lateral losses, tailwater and precipitation runoff are subject to non-crop evapotranspiration based on the SEV factor. The remaining unconsumed water is returned to the river. A summary of the input data in LAND.DAT is included in Attachment 6.10.

1.5.4. GWFLOW Subroutine

The GWFLOW subroutine simulates the interaction of the groundwater system with the stream system using unit response functions. The unit response functions for each user were derived from groundwater models of the valley fill aquifer and the surficial or bench aquifers. The unit response functions represent the effect of a unit of recharge or pumping on the river and account for the effects of recharge from surface water irrigation, recharge from groundwater irrigation, and the discharge from groundwater pumping on the river.

The GWFLOW subroutine reads in data from three data files: SWRESP.DAT, GWRESP.DAT and CNRESTP.DAT. The GWFLOW subroutine calculates return flows from applied irrigation water (SWRESP.DAT), groundwater pumping (GWRESP.DAT) and canal seepage losses for the Fort Lyon Canal and the Amity Canal. For other users, it is assumed that the timing of return flows from canal seepage losses is the same as the return flows from applied irrigation water. However, because the Fort Lyon Canal and the Amity Canal are very long canals that go outside the Valley Fill Aquifer, separate canal response functions were developed for those canals. Attachment 6.11 shows the H-I Model reaches to which spills, pumping effects and return flows are assigned.

1.5.5. ROUTE Subroutine

The ROUTE subroutine provides a river budget accounting for each river reach in the H-I Model. This involves accounting, in each reach, for the inflow from the upstream reach, the tributary inflow, canal diversions, surface water return flows, the effects of groundwater pumping and recharge from irrigation and groundwater, phreatophyte consumptive use, river evaporation and the outflow for each reach of the river. The ROUTE subroutine opens output files and initializes variables.

1.5.6. BUDGET Subroutine

The BUDGET subroutine summarizes the overall monthly system water budget and computes a cumulative mass balance residual of the budget terms that should be close to zero. (There are some minor non-zero residuals due to mathematical rounding.) The BUDGET subroutine writes a water budget to an output file.

2. H-I Model Inputs

Inputs to the H-I Model include gaged and ungaged tributary inflows, phreatophyte consumption, precipitation, water right appropriation dates and amounts, transmountain deliveries, WWSP deliveries, irrigated acreage, soil moisture holding properties, canal and lateral seepage factors, potential evapotranspiration (PET) and pumping amounts. Other inputs include canal and reservoir capacities,

WTFACT and WTADD factors, non-crop evaporation (SEV) factors and diversion reduction factors (DRF). The inputs are discussed in more detail in the discussion of the H-I Model subroutines and the data files read in by each subroutine. Some of these inputs are computed values from other basic data.

For instance, in the update files PET is determined through a pre-processing analysis based on local climate data. The inputs for PET include weather data obtained from electronic weather stations appropriately situated in the Arkansas River Valley. With these data, PET is computed using the Penman-Monteith equation and crop coefficients. This PET establishes the ET that would have occurred if the crop was at a specified stage of growth with a full supply of water. The PET is affected by the type of crop, its stage of growth, wind speed and solar radiation. PET is the ideal or maximum ET one might expect when there is a full water supply. Actual crop ET is computed in the H-I Model as the lesser of the PET or the simulated water supply made available to the crop.

Stream-aquifer interactions are represented in the H-I Model with unit response functions for groundwater pumping and deep percolation of applied irrigation water. During the early stages of the H-I Model development, groundwater models were used to develop these response functions for each of the H-I Model users.

The following discussion describes the files read in by each subroutine and the variables used.

2.1. *Input Files for Subroutine SUPPLY*

The SUPPLY subroutine reads in four data files: SUPPLY0.DAT, TREES.DAT, PRCP.DAT and RESR. DAT.

2.1.1. SUPPLY0.DAT – The variables used in SUPPLY0.DAT include:

2.1.1.1. JREACH (IRCH, ISTA) – the reach assignment for tributary inflows; and

2.1.1.2. FLOW (IMONTH, IFLOW) – the tributary inflows for each tributary "station." See Figures 4 and 10 and Attachment 6.4.

2.1.2. TREES.DAT contains phreatophyte consumptive use along the Arkansas River for the years 1950-1994. The variables used in TREES.DAT are (IUSE, IMONTH). TREES.DAT is used in conjunction with Data Set 2 to determine the rate of phreatophyte consumption beginning in 1995.

2.1.3 PRCP.DAT contains precipitation data for the years 1950-1994. The variables used in PRECIP are (IUSE, IMONTH). PRCP.DAT is used in conjunction with Data Set 3 to determine monthly precipitation beginning in 1995.

2.1.4. RESR.DAT – The variables used in RESR.DAT include:

2.1.4.1. EVARATE (IMONTH) – evaporation rates;

2.1.4.2. RECHLN (IRCH) – river reach length;

2.1.4.3. JPPT (IRCH) – user number with same precipitation as this reach; and

2.1.4.4. RIVARE – river area (4,200 acres).

RESR.DAT also contains data to calculate reservoir evaporation, which is read in by subroutine GET.

2.1.5. Parameter Dimensions – The dimensions used are 21 for IRCH, 10 for ISTA, 46 for IFLOW and 25 for IUSE. The dimension for IMONTH is increased each year to account for the addition of 12 months.

2.2. Input Files for Subroutine GET

The GET subroutine reads in eight data files: RIGHT.DAT, TMOUNT.DAT, WINTER.DAT, QDAY.DAT, RESR.DAT, PUMP.DAT, PUMP48.DAT and WTFACT.

2.2.1. RIGHT.DAT – The variables used in RIGHT.DAT include:

2.2.1.1. NRES – number of reservoirs;

2.2.1.2. IU1 – first diversion below John Martin Reservoir (User 15);

2.2.1.3. IU2 – last diversion above the Stateline (User 23);

2.2.1.4. JRCH – river reach from which diversion to storage is made;

2.2.1.5. WFACTU and WFACTD – a calibration factor used to adjust WANT (currently set at 1);

2.2.1.6. JR (IDVT) – reach from which diversion is made;

2.2.1.7. WRFACT (IDVT) – Colorado Water District 67 user's percentage of John Martin Reservoir releases to Colorado before 1980;

2.2.1.8. UTYPE (IDVT) – user type (1 = direct diversion; 2 = reservoir);

2.2.1.9. URES (IDVT) – number assigned to reservoirs in the H-I Model;

2.2.1.10. IDS (IDVT) – diversion above (0) or at or below (1) John Martin Reservoir;

2.2.1.11. NSOUR1 (IDVT) – the number of primary groundwater sources (1 = groundwater use only);

2.2.1.12. NSOUR2 (IDVT) – the number of water rights that can be diverted from the river;

2.2.1.13. NSOUR3 (IDVT) – the number of supplemental groundwater and reservoir sources;

2.2.1.14. JRCAN (IDVT) – the user number of the canal that delivers water to an off-channel reservoir;

2.2.1.15. STYPE (IDVT, ISOUR) – source type (1 = canal; 2 = reservoir; 3 = groundwater);

2.2.1.16. UMAX (IDVT, ISOUR) – the maximum diversion (calibrated canal capacity) for the user;

2.2.1.17. JRESR (IDVT, ISOUR) – a reservoir identifier;

2.2.1.18. OWNER (IRIGHT) – the owner identifier for the storage right;

2.2.1.19. JRCH (IRIGHT) – the reach in which the water right is diverted;

2.2.1.20. RMAX (IRIGHT) –the amount of each of the water rights decreed for diversion (cfs) or storage (acre-feet) from the priority list;

2.2.1.21. STOR0 (IRES) – the starting reservoir storage on January 1, 1950;

2.2.1.22. STRMIN (IRES) – reservoir storage that cannot be released (dead storage);

2.2.1.23. STRMAX (IRES) – the maximum reservoir storage;

2.2.1.24. KSDEM (IMONTH) – the Kansas threshold demand (for pre-1980 Stateline demand);

2.2.1.25. KSCL (IMONTH) – the Kansas historical call (for Stateline demands beginning in 1980);

2.2.1.26. JMPERC (MAXUSE) – Colorado Water District 67 user's percentages of John Martin Reservoir releases from conservation storage to Section II accounts under the 1980 Operating Plan; and

2.2.1.27. SLCALL (IMONTH) – the maximum Stateline call by Kansas (for pre-1980 Stateline demands).

2.2.2. TMOUNT.DAT contains transmountain deliveries for nine users for the years 1950-1994. The variables used are TRANSM (IUSE, IMONTH). TMOUNT. DAT also contains transit loss conveyance factors used to remove transmountain water from the Pueblo Composite Gage in the Compact run. The variables used are TRLOSS (IUSE). TMOUNT.DAT is used in Date Set 14 under certain preprocessor settings.

2.2.3. WINTER.DAT contains WWSP deliveries from Pueblo Reservoir and related data for the years 1950-1994. The variables used in WINTER.DAT include:

2.2.3.1. WWPBIN (IMONTH) – winter water inflows to Pueblo Reservoir prior to 1995 (This file is not part of the annual update file.);

2.2.3.2. WWPB (IUSE, IMONTH) – the WWSP deliveries to nine users; and

2.2.3.3. WWSPLL (IMONTH) – winter water spills from Pueblo Reservoir.

WINTER.DAT is used in Data Set 13 under certain settings.

2.2.4. QDAY.DAT contains the daily flows of the Arkansas River measured at the streamflow gage near Pueblo (USGS 07099500) for 1950-1975 and the Arkansas River above Pueblo (USGS 07099400, or ARKPUECO) for 1965[**?**]-1994 and the Las Animas Purgatoire River Gage (USGS 07218500) for the years 1950-1994. Updated data for these streamflows are contained in Data Set 10 and Data Set 8.

2.2.5. RESR.DAT contains data used to calculate monthly lake evaporation from John Martin Reservoir for the years 1950-1994. The storage area relationship

factors alpha and beta are represented in RESR.DAT as:

2.2.5.1. EVAP (IMONTH),

2.2.5.2. ALPHA (IPER, IRANGE), and

2.2.5.3. BETA (IPER, IRANGE).

2.2.6. PUMP.DAT and PUMP48.DAT contain the monthly historical pumping and the monthly pre-compact pumping allowance, respectively, for each user for the years 1950-1994. The variables used are:

2.2.6.1. PUMPOB (IUSE, IMONTH); and

2.2.6.2. PUMP48 (IUSE, IM).

2.2.7. WTFACT.DAT contains WTADD (IDVT,IM) and WTFACT (IDVT,IM) factors used to compute WANT.

2.3. *Input Files for Subroutine LAND*

The LAND subroutine reads in three data files: LAND.DAT, PET.DAT and SEV.DAT.

2.3.1. LAND.DAT – The variables used in LAND.DAT are:

2.3.1.1. AWCFAC – a threshold factor value of soil moisture (64%);

2.3.1.2. AREA2 (IUSE), AREA (IUSE), AREA3 (IUSE) – the irrigated acreages for each user for

1969-1985, 1950-1968 and 1986-1994, respectively;

2.3.1.3. ATYPE (IUSE, ITYPE) – partitions irrigated acreages for each user into three types: surface water only, groundwater only, and surface and groundwater;

2.3.1.4. FME (IUSE) – the maximum farm efficiency for each user;

2.3.1.5. ETFACT, ZFACT, SEEFAC – calibration parameters no longer used;

2.3.1.6. IRTRCH (IUSE) – the river reach that spills are returned to for each user;

2.3.1.7. SPILLF (IUSE) – a spill factor that can be used for each user;

2.3.1.8. RFACT (IUSE, IRCH) – a factor for returning surface runoff for each user;

2.3.1.9. AWC (IUSE) – the available soil water-holding capacity by user area;

2.3.1.10. THEATA0 (IUSE) – the starting soil moisture by user area;

2.3.1.11. Z (IUSE) – the average rooting zone depth by user area;

2.3.1.12. SEEPFC (IUSE) – a factor to calculate canal seepage by user;

2.3.1.13. SEEPFL (IUSE) – a factor to calculate lateral seepage by user;

2.3.1.14. TAILF (IUSE) –a factor to calculate tailwater by user; and

2.3.1.15. LENGTH (IUSE) – the canal length by user.

2.3.2. PET.DAT contains the monthly PET values for each user for the years 1950-1994 (IUSE, IMONTH), which were calculated using the modified Blaney-Criddle method, then adjusted using adjustment ratios developed by using the Penman-Monteith equation and crop coefficients for irrigated crops. The dimensions of the variables are 25 for IUSE, 21 for IRCH, 432 for IMONTH and ITYPE is 3.

2.3.3. SEV.DAT contains calibrated factors used to calculate non-crop evaporation.

2.4. *Input Files for Subroutine GWFLOW*

The GWFLOW subroutine reads in three data files: SWRESP.DAT, GWRESP.DAT and CNRESP.DAT.

2.4.1. SWRESP.DAT – The variables used in SWRESP.DAT are:

2.4.1.1. NFUNSW (IUSE) – the number of surface water response functions;

2.4.1.2. RECH0 (IUSE, IELE) – groundwater recharge for 1940-1949;

2.4.1.3. JRECHS (IUSE, IFU) – the surface water response function river reach;

2.4.1.4. GWRFSW (IUSE, IFU, IELE) – the groundwater recharge function with the surface water response function.

2.4.2. GWRESP.DAT – The variables used in GWRESP.DAT are:

2.4.2.1. NFUNGW (IUSE) – the number of groundwater response functions;

2.4.2.2. PUMP0 (IUSE, IELE) – the pumping for 1940-1949 (total = 24,032 acre-feet per year);

2.4.2.3. JRECHG (IUSE, IFU) – the groundwater response function river reach;

2.4.2.4. GWRFGW (IUSE, IFU, IELE) – the groundwater recharge function with groundwater response; and

2.4.2.5. SSFLUX (IRCH) – steady state flux.

The dimensions used in these files are 25 for IUSE, 120 for IELE, 10 variable for IFU and 21 for IRCH.

2.4.3. CNRESP.DAT contains the canal seepage response functions for the Fort Lyon Canal (User 10) and the Amity Canal (User 17). The variables used in CNRESP.DAT are:

2.4.3.1. NFUNCN – the number of reaches with response functions;

2.4.3.2. SEEPO – the pre- 1950 canal seepage;

2.4.3.3. JRECHC (NFUNCN) – the reach number; and

2.4.3.4. GWRFCN – the monthly canal seepage to the specified reach.

3. H-I Model Operation

3.1. *H-I Model Code*

The H-I Model code is on the DVD. This version of the program is the same as the program used to determine depletions to usable Stateline flows for the 1995-96 period with the following changes: (1) modified to run an automated calibration procedure; (2) modified to include interception of Fort Lyon return flows to Reaches 13 and 14 by the Amity Canal (100% of surface water returns and no groundwater returns); (3) modified to reroute a portion of Reach 7

returns to the reach below the Fort Lyon Canal headgate; and (4) reads WANT factors and SEVs from WTFACT.DAT and SEV.DAT in the HIM\calib\directory.

1. Batch Run File – \HIM\new\deple.bat
2. Input File Directories
    a. For H-I Model – \HIM\data\
    b. Original Files – \HIM\data\original\
    c. Save Runs – \HIM\data\new\
3. Output File Directories
    a. From H-I Model – \HIM\out\
    b. Saved Runs – \HIM\out\new\
    c. Current Final Runs (1950- 2006) Historic – \HIM\out\new\ \

3.2. Input Files for Model Updates Beginning in 1995

Beginning in 1995, data required to update the H-I Model's input files are placed into a single file for a specific year, named Rdyyyy.DAT, where yyyy is the calendar year.

A series of BASIC programs arranged in a batch file named UPDATE.BAT are used to process the data contained in Rdyyyy.DAT and write annual data files (UPDATEyy.DAT). A single file, UPDATE.DAT, is then constructed by merging all of the UPDATEyy.DAT files.

The following sections describe the data sets that are used to update the H-I Model's input files beginning in 1995. In some cases, the States have agreed to use data sets for additional or different purposes than described, however, to represent new operations on the river. It should be noted that not all data in the input files to the H-I Model are updated. For example, canal capacities, reservoir capacities and calibrated factors such as WTFACTs, WTADDs and SEVs do not change.

3.2.1. Data Requirements for Rdyyyy.DAT

Each annual update file is arranged in data files, called data sets. Each data set is preceded by comments identifying the data set and the data requirements and the comment "C START DATA." This comment is used by the processing files to identify the starting point of the numerical data in the data set and must immediately precede the data. The second row in each data set containing a single value is a flag that determines how the data in the data set are to be processed by the program. A flag is not present if the second row contains more than a single value, in which case the data set begins immediately with the data.

3.2.1.1. Data Set 1 – Daily Pan Evaporation for John Martin Reservoir

This data set contains data used to determine monthly river and reservoir evaporation; the data are obtained from the U.S. Army Corps of Engineers (Corps).

The first value in the second row of the data set is a flag, where 0 means that values for daily pan evaporation and reservoir ice cover are supplied immediately following the flag. This value is the normal flag setting for this data set. If the flag is set to -N, the average of N years is computed using the file RESR.DAT, with 1994 as the last year in the average. For example, -10 means the average of ten years is computed beginning in 1985 and ending in 1994.

A partial example in tabular form of Data Set 1 for January and February of a sample year is shown below. The data are represented in a tab-delimited data set. The 1st row is the comment "C START DATA;" the 2nd row is the flag (in this case 0); the 3rd, 4th and 5th rows are the 31 daily values for pan evaporation for January. The 6th, 7th and 8th rows are the 31 daily values of ice cover percentage for January. The 9th, 10th and 11th rows are the 28 daily values for pan evaporation for February. The 12th, 13th and 14th rows are the 28 daily values of ice cover percentage for February. The data set would then continue with daily values for the same two sets of data for the other months in the year.

C START DATA

0 *[flag]*

0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143
0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143
0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143	0.1143		
30	30	30	30	30	30	30	30	30	30	30
30	30	30	30	30	30	30	30	30	30	30
30	30	30	30	30	30	30	30	30		
0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300
0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300
0.1300	0.1300	0.1300	0.1300	0.1300	0.1300					
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0					

ETC.

3.2.1.2. Data Set 2 – Phreatophyte Consumption

This data set is used to determine the phreatophyte consumption for each month and each of the 18 H-I Model river reaches starting in 1995. It contains only a flag in the second row of the data set, where 0 means the processing program uses the file TREES.DAT to project the phreatophyte consumption beginning in 1995 at the 1958-1994 rate of increase. If the flag is set to -1, the processing program uses the 1994 values from TREES.DAT. The data are represented in a tab-delimited data set.

An example of Data Set 2 is shown below.

C START DATA
0 *[flag]*

3.2.1.3. Data Set 3 – Monthly Precipitation

This data set contains monthly precipitation in hundredths of inches for six stations, which is used to calculate the monthly precipitation in each of the 23 H-I Model user areas. The monthly precipitation data in this data set are obtained from the National Oceanic and Atmospheric Administration (NOAA). The data are represented in a tab-delimited data set.

The first value in the second row of the data set is a flag, where 0 means that the data supplied in the rows following the flag are monthly precipitation data from six stations in the following order (the station identifications are in parentheses). This value (0) is the normal flag setting for this data set:

1. PUEBLO WSO AP (056740)
2. ROCKY FORD (057167)
3. LA JUNTA 4NNE (054720)
4. LAS ANIMAS (054834)
5. LAMAR (054770)
6. HOLLY (054076)

Any missing data must be replaced in this data set.

If the flag value is set to -N, an average for N years is computed using the input file PRCP.DAT, with 1994 as the last year in the average.

An example of Data Set 3 under normal conditions is shown below.

C START DATA

0 *[flag]*

1	16	88	252	430	228	118	257	138	0	14	0
9	17	100	189	402	287	150	41	68	0	0	1
22	26	173	214	475	210	179	114	74	0	4	4
50	17	96	263	696	480	169	45	133	3	0	3
60	24	108	264	427	348	90	77	62	4	0	5
40	34	100	189	455	233	328	75	119	8	4	5

3.2.1.4. Data Set 4 – Annual Precipitation

This data set contains annual precipitation data in hundredths of inches for 20 stations that are used to calculate ungaged tributary inflows. The data are represented in a tab-delimited data set. The data in this data set must be supplied in the following station order (identifications in parentheses are the cooperator numbers as assigned by Western Regional Climate Center (www.wrcc.dri.edu)):

1. Trinidad FAA Airport (058434) (Aguilar prior to 2005)
2. Cheyenne Wells (051564)
3. Colorado Springs Municipal Airport (051778)
4. Colorado Springs Municipal Airport (051778) (Fountain prior to 1997)
5. Haswell (053828)
6. Holly (054076)
7. John Martin Dam (054388)
8. Karval (054444)
9. Lamar (054770)
10. La Junta 4 NNE (054720)
11. Las Animas (054834)
12. Genoa (053258); Limon prior to 1995
13. Ordway 2 ENE (056131)
14. Pueblo Mem Airport (056740)
15. Rocky Ford 2 SE (057167)
16. Campo 7S (051268) (Springfield, prior to 2002)
17. Tacony 10 SE (058157)

18. La Junta 20S (054726) (Timpas prior to 1993)
19. Walsenburg 1 NW (058781)
20. Walsh 1 W (058793)

Missing data is indicated by -99. In some years, annual precipitation data are not available for all stations and data from other stations are substituted.

An example of Data Set 4 is shown below.

C START DATA

18.66	19.33	22.26	22.26	19.24	15.90	18.82	16.01	14.69	14.95
19.55	-99	15.61	15.42	12.64	15.20	12.30	-99	16.67	18.43

3.2.1.5. Data Set 5 – Monthly Diversion Data Used to Create the Pueblo Composite Gage

This data set contains monthly diversion data in acre-feet that are used to create the monthly streamflow of the Arkansas River at the Pueblo Composite Gage. The data are represented in a tab-delimited data set. Monthly diversions for five structures are provided in the following order:

1. Riverside Dairy Ditch (CDWR 14-536)
2. Southside Water Works (CDWR 14-590)
3. Northside Water Works (CDWR 14-589)
4. Comanche Power Plant Intake (CDWR 14-618)
5. Bessemer Ditch (CDWR 14-533), excluding Lake Minnequa (CDWR 14-3693), St. Charles Mesa Water Association (CDWR 14-645), or Zoeller Ditch (CDWR 14-527) or other water carried in Bessemer Ditch.

An example of Data Set 5 is shown below.

C START DATA											
0	0	0	0	13.4	54.7	44.8	79.5	42.9	24.5	0	0
0	0	0	0	0	0	0	0	0	0	0	0
1120	1147	1453	1459	2039	2848	4974	30332	4678	4319	1193	1052
546	248	495	809	713	768	823	943	751	884	348	256
0	0	2763	5284	9229	11351	16505	15709	12643	6293	0	0

3.2.1.6. Data Set 6 – Monthly Tributary and Waste Water Return Flow Data Used to Create the Pueblo Composite Gage and Tributary Inflow to Reach 1

The first two items in this data set are used to create the monthly streamflow of the Arkansas River at the Pueblo Composite Gage; the last two items are included in the tributary inflow to Reach 1. The data are represented in a tab-delimited data set. Monthly stream and return flow data in acre-feet must be supplied in the following order:

1. Fountain Creek at Pueblo (USGS 07106500)
2. Pueblo waste water return (CDWR 14-620)
3. Salt Creek (Data prepared by Rocky Mountain Steel Mill and provided by CDWR)
4. St. Charles River (USGS 07108900)

An example of Data Set 6 is shown below.

C START DATA

8080	8040	8810	13160	73030	51520	26400	8120	9270	8670	9210	8550
1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
5000	6000	6000	6000	6000	6000	6000	6000	5000	5000	5000	5000
510	426	412	3210	19480	14100	6640	1180	762	1400	4730	712

3.2.1.7. Data Set 7 – Daily Streamflows for the Apishapa River

This data set contains daily streamflows in cubic feet per second (cfs) for the Apishapa River (USGS 07119500) that are used to compute monthly inflows for tributary station 14 (the Apishapa River) and the daily tributary inflows to Reach 5 of the H-I Model. The data are represented in a tab-delimited data set. The array consists of 31 rows by 13 columns. The value in the first column is the day of the month. The values in the second through 13th columns are the flows for that day for each month. If the month has less than 31 days or there is a missing value, -99 is used in those cells.

A partial example of Data Set 7, showing the values for the first and second days of each month for a year, is shown below.

```
C START DATA
1     3.4   3.5   2.3   6.6   28    84    41    13    21    22    28    29
2     3.4   3.4   2.3   4.6   23    72    65    12    21    22    26    29
ETC.
```

3.2.1.8. Data Set 8 – Daily Streamflows for the Purgatoire River PURG.DAT

This data set contains daily streamflows in cfs for the Purgatoire River near Las Animas (USGS 07128500) that are used to compute monthly inflows for tributary station 23 (the Purgatoire River) and the daily tributary inflows to Reach 10 of the H-I Model. See Data Set 7 for the form and an example of the data array. The data are represented in a tab-delimited data set. If the month has less than 31 days or there is a missing value, -99 is used in those cells.

3.2.1.9. Data Set 9 – Daily Streamflows for the Huerfano River HUERFANO.DAT

This data set contains daily streamflows in cfs for the Huerfano River (USGS 07116500) that are used to compute monthly inflows for tributary station 8 (the Huerfano River) and the daily tributary inflows to Reach 3 of the H-I Model. See Data Set 7 for the form and an example of the data array. The data are represented in a tab-delimited data set. If the month has less than 31 days or there is a missing value, -99 is used in those cells.

3.2.1.10. Data Set 10 – Daily Streamflow for the Arkansas River above Pueblo

This data set contains daily streamflows in cfs for the Arkansas River above Pueblo (USGS 07099400) that are used to compute monthly inflows for tributary station 1 (the Pueblo Composite Gage) and the daily tributary inflows to Reach 1 of the H-I Model. See Data Set 7 for the form and an example of the data array. The data are represented in a tab-delimited data set. If the month has less than 31 days or there is a missing value, -99 is used in those cells.

3.2.1.11. Data Set 11 – Monthly Discharge from the Lamar Power Plant

This data set contains monthly discharge data in acre-feet for the Lamar Power Plant that are added to the Lamar/Manvel Canal water supply in the H-I Model. The Lamar Power Plant historically discharged cooling water into the Lamar Canal. The water discharged into the Lamar Canal is measured and charged against diversions under the Lamar Canal water rights if the water is not returned to the river. The data are represented in a tab-delimited data set. The first value in the second row of the table is a flag, where 0 means monthly discharges are supplied immediately following the flag. This value is the normal flag setting for this data set.

If the flag is set to -N, the average of N years is computed using the file RIGHT.DAT, with 1994 as the last year in the average.

An example of the data set file is shown below.

```
C START DATA
0 [flag]
1039  978  812  658  708  845  938  950  800  558  683  823
```

3.2.1.12. Data Set 12 – Monthly Pumping for H-I Model Users

This data set contains monthly pumping in acre-feet for H-I Model users and consists of two arrays, each consisting of 24 rows (users) and 12 columns (months). The data are represented in a tab-delimited data set. The first array contains the monthly pumping by each user for pumping used to supplement surface water (conjunctive use). (The supplied pumping for User 20 is 0.) Pumping in canal service areas where the canal capacity has been set to 0 in the Historical run, such as Booth-Orchard, Excelsior, X-Y Graham and Sisson-Stubbs, is included in this data set. Pumping for users 14 and 24 (groundwater only users) is entered as 0 in the first array. The second array contains monthly pumping used as a sole source of supply in user areas.

A partial example of the data arrays is shown below.

```
C START DATA
 0   0   0   344   963   966   992  1186   412   363     0     0
 0   0   0   166   270   170   145   271   109   138     0     0
```

3.2.1.13. Data Set 13 – Monthly WWSP Deliveries from Pueblo Reservoir to H-I Model Users

This data set contains monthly WWSP deliveries in acre-feet from Pueblo Reservoir to nine H-I Model users. WWSP water used for replacement is also added to this data set and deducted from the Historical run using Data Set 23. The data are represented in a tab-delimited data set. The first value in the second row of the data set is a flag, where 0 means monthly WWSP deliveries from Pueblo Reservoir are supplied immediately following the flag in the order shown below. This value is the normal flag setting for this data set.

If the flag value is set to -N, the average of N years is computed using the file WINTER.DAT, with 1994 as the last year in the average.

The order of the nine users to be supplied when the flag is 0 is as follows:

1. Bessemer (CDWR 14-533)
2. Catlin (CDWR 17-552)
3. Colorado Canal (CDWR 17-540)
4. Las Animas Consolidated (CDWR 17-556)
5. Fort Lyon (CDWR 17-553)
6. Rocky Ford Highline (CDWR 17-556)
7. Holbrook (CDWR 17-554)
8. Otero (CDWR 17-557)
9. Oxford (CDWR 17-541)

An example of Data Set 13 is shown below.

C START DATA

0 *[flag]*

0	0	0	296	221	0	5008	2879	0	0	0	0
0	0	1664	6449	0	0	0	5461	0	0	0	0
0	0	0	283	10	0	0	77	82	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	327	0	0	0	3921	4304	0	0	0	0
0	0	0	0	0	0	0	3005	3101	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	63	699	0	0	1051	1707	0	0	0	0

3.2.1.14. Data Set 14 – Monthly Transmountain Deliveries to H-I Model Users

This data set contains monthly transmountain deliveries in acre-feet through the Pueblo Composite Gage to nine H-I Model users. The data are represented in a tab-delimited data set. The deliveries in this data set also include deliveries of native water from Twin Lakes Reservoir.

The first value in the second row of the data set is a flag, where 0 means monthly deliveries (measured at each user's headgate) are supplied immediately following the flag in the order shown below. This value is the normal flag setting for this data set.

If the flag value is set to -N, the average of N years is computed using the file TMOUNT.DAT, with 1994 as the last year in the average. If the flag value is set to YYYY (a range of 1950-1994), deliveries from the file TMOUNT.DAT for the specified year are used.

The order of the nine users to be supplied when the flag is 0 is as follows:

1. Bessemer (CDWR 14-533)
2. Excelsior (CDWR 14-539)
3. Colorado Canal (CDWR 17-540)
4. Rocky Ford Highline (CDWR 17-542)
5. Oxford (CDWR 17-541)
6. Otero (CDWR 17-557)
7. Catlin (CDWR 17-552)

8. Fort Lyon (CDWR 17-553)
9. Holbrook (CDWR 17-554)

An example of Data Set 14 is shown below.

C START DATA

0 *[flag]*

0	0	0	0	0	835.1	4397.8	2999.1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1919	10780	1437.1	2581	2721	0	0	0
0	0	539	2851.3	991.8	1852.1	5229.1	0	0	0	2.3	0
0	0	0	0	0	0	908.3	39.7	236.8	32.2	0	0
0	0	68.5	111.2	69.3	100.9	179.8	305.8	287	0	0	0
0	0	0	0	35	54	6601.0	946.0	0	0	0	0
0	0	0	0	0	0	16887	0	0	0	182.3	0
0	0	63	699	0	0	4317.7	3151.3	0	0	0	0

3.2.1.15. Data Set 15 – Monthly Transmountain Return Flows in the Inflows from Fountain Creek

This data set contains monthly transmountain return flows in acre-feet in the inflows from Fountain Creek to the Arkansas River that are not exchanged to Pueblo Reservoir or other reservoirs upstream from Pueblo Reservoir or delivered to reservoirs in the H-I Model Domain. The data are in a tab-delimited data set. An example of Data Set 15 is shown below.

```
C START DATA
0   0   0   0   0   0   0   0   200   0   0   0   0
```

3.2.1.16. Data Set 16 – Daily Transmountain Deliveries to the Colorado Canal

This data set contains daily transmountain deliveries in cfs to the Colorado Canal, which are used to calculate the daily transmountain factor for the Colorado Canal. The data are in a tab-delimited data set. The array consists of 31 rows by 13 columns. In this data set, 0 (zero) is used for the 29th, 30th and 31st days of months that do not have those days. See Data Set 7 for the 31 by 13 data array format and organization of this array.

3.2.1.17. Data Set 17 – Daily Diversions for the Fort Lyon Canal, the Fort Lyon Storage Canal and the Kickingbird Canal

This data set contains daily diversions in cfs for the Fort Lyon Canal, the Fort Lyon Storage Canal and the Kickingbird Canal, which are used to calculate a winter direct-flow diversion factor for the Fort Lyon Canal. The data are represented in a tab-delimited data set. The first value in the second row of the data set is a flag, where 0 means three diversion arrays are supplied in the following order: 1) the Fort Lyon Canal daily diversions, 2) the Fort Lyon Storage Canal daily diversions, and 3) the Kickingbird Canal daily diversions. The Kickingbird Canal daily diversions are the deliveries as measured at the bifurcation structure on the Fort Lyon Canal. This value is the normal flag setting for this data set.

If the flag value is set to 1, the monthly factors are set to 0. See Data Set 7 for the 31 by 13 data array format and the organization for each of the three arrays.

3.2.1.18. Data Set 18 – Native Component of Twin Lakes Reservoir Water Delivered to the Colorado Canal

This data set is used to calculate the native Twin Lakes Reservoir water delivered to the Colorado Canal contained in the deliveries in Data Set 14. This data is obtained from the records of the Twin Lakes Reservoir & Canal Company. The data are represented in a tab-delimited data set. The first value in the second row of the data set is the percentage (written in the decimal system) of the Twin Lakes Reservoir deliveries that is native water. The values in the third row of the data set are the monthly Twin Lakes Reservoir deliveries in acre-feet to the Colorado Canal. An example of Data Set 18 is shown below.

C START DATA

0.3474

0	0	0	5229	1902	10514	933	1685	1980	0	0	0

3.2.1.19. Data Set 19 – Deliveries of Transmountain Water to the Permanent Pool in John Martin Reservoir

This data set contains monthly deliveries in acre-feet of transmountain water through the Pueblo Composite Gage for storage in the permanent pool in John Martin Reservoir. The permanent pool in John Martin Reservoir is not simulated in the H-I Model; deliveries to the permanent pool are not added to modeled storage in John Martin Reservoir and are subtracted from the Pueblo Composite Gage.

The first value in the second row of the data set is the annual number of deliveries to the permanent pool. If there are no deliveries during the year, then 0 is used. The values in the third and subsequent rows are the month of the delivery and the total delivery in acre-feet for the month. An example of Data Set 19 is shown below.

C START DATA	
2	
6	4000
7	1200

3.2.1.20. Data Set 20 – Monthly Exchanges to a Location Upstream from Pueblo Composite Gage

This data set contains monthly releases in acre-feet of consumable water from within the H-I Model Domain that is exchanged to Pueblo Reservoir. It includes Lake Meredith releases and discharges of consumable water from various canals that are exchanged to a location upstream from the Pueblo Composite Gage. An exchange involves the diversion or storage of water at an upstream location and providing substituted water at a downstream location to satisfy the requirements of senior water rights. For convenience, such exchanges will be described as exchanges from one location to another. This data set is used for exchanges of replacement sources into Pueblo Reservoir for storage and later release. The data are represented in a tab-delimited data set. To account for these exchanges in the H-I Model, they are added to the Pueblo Composite Gage and become part of the natural river flow available for diversion by other users in the H-I Model.

The first value in the second row of the data set is the annual number of releases. If there is more than one release during the month, all releases during the month are considered one release and the amounts of the releases are combined. If there are no releases during the year, 0 is used. The values in third and subsequent rows are the month in which a release was made and the total release in acre-feet for

the month. See Data Set 19 for an example of this data set.

3.2.1.21. Data Set 21 – Releases from Lake Meredith that are Exchanged to Trinidad Reservoir and Removal of Water from the Purgatoire River Gage

This data set contains monthly releases in acre-feet of consumable water from Lake Meredith that are exchanged to Trinidad Reservoir. This data set is also used for Highland Ditch deliveries to the Offset Account from the Purgatoire River Gage, by using negative values. The data are represented in a tab-delimited data set. To account for these exchanges in the H-I Model, they are added to the tributary inflow to Reach 10 and become part of the natural river flow available for diversion by other users in the H-I Model.

The first value in the second row of the data set is the annual number of releases. If there is more than one release during the month, all releases during the month are considered one release and the amounts of the releases are combined. If there are no releases during the year, then 0 is used. The values in third and subsequent rows are the month in which a release was made and the total release in acre-feet for the month. See Data Set 19 for an example of this data set.

3.2.1.22. Data Set 22 – Deliveries to the River or Removal of Water from the River as part of Replacement Operations

This data set contains monthly deliveries in acre-feet of consumable water as part of Replacement operations. Examples include releases of consumable water from Lake Meredith, recharge credits from the Excelsior Ditch recharge pond, unconsumed Offset Account transit losses as described in the Offset Account Crediting Agreement (Appendix F.2 of this Decree), and unconsumed transit losses from deliveries of Highland Ditch credits to the Offset Account. Negative values are used to remove water from the river flows or inflows to the H-I Model to represent certain Replacement operations, such as diversions to the Excelsior Ditch recharge pond, and Keesee Ditch inflows to the Offset Account. The deliveries are added to, or removals are made from, a specified river reach when the transmountain switch is on (JTM=1) (i.e., the Historical run). The deliveries offset depletions due to pumping.

The first value in the second row of the data set is the annual number of releases. The three values in the third and subsequent rows are the month of the release (or the removal), the specified river reach, and the monthly amount in acre-feet of the delivery (or the monthly amount in acre-feet of the removal). An example of Data Set 22 is shown below.

```
C START DATA
3
7       14      100
8       14      120
7       7       321
```

3.2.1.23. Data Set 23 – Releases from Lake Meredith for Irrigation Use

This data set contains monthly releases in acre-feet of consumable water from Lake Meredith to H-I Model users for irrigation use. Releases from Lake Meredith that are made in exchange for diversions at the Colorado Canal are not included in this data set. This data set is also used to subtract WWSP deliveries for canals in the Historical run that are added to H-I Model users through Data Set 13, by using negative values. The data are represented in a tab-delimited data set. These releases are added to Reach 1 and the transmountain water supply when the transmountain switch is on (JTM=1). Return flows from these releases offset depletions due to pumping.

The first value in the second row of the data set is the annual number of releases. If there are no releases during the year, then 0 is used. The three values in the third and subsequent rows are the month of the release, the user receiving the release and the monthly amount in acre-feet of the release. An example of Data Set 23 is shown below.

```
C START DATA
1
5                                   9                                   6040
```

3.2.1.24. Data Set 24 – Releases from Lake Meredith to the Great Plains Reservoirs for Sales to Colorado DOW and DPOR

This data set contains monthly releases in acre-feet of consumable water from Lake Meredith sold to Colorado Division of Wildlife (DOW) or Division of Parks and Outdoor Recreation (DPOR) for storage in the Great Plains Reservoirs for non-irrigation use. This data set facilitates the calculation of canal seepage from the Fort Lyon and Kickingbird Canals on such deliveries. Deliveries of water from Lake Meredith to the Great Plains Reservoirs for non-irrigation use as in these sales are not added to the irrigation supply for the Amity Canal because storage for non-irrigation purposes in the Great Plains Reservoirs is not simulated in the H-I Model. The data are represented in a tab-delimited data set. Canal seepage is computed when the transmountain switch is on (JTM=1). This data set has been used to date one time for the delivery of 13,518 acre-feet in 1996 during April, May and June.

The first value in the second row of this data set is the annual number of releases. The two values in the third and subsequent rows are the month of the release and the monthly amount of the release in acre-feet. If there are no releases during the year, 0 is used. See Data Set 19 for an example of the form and format of this data set.

3.2.1.25. Data Set 25 – Deliveries of Transmountain or Other Consumable Water through the Pueblo Composite Gage for Replacement of Well Depletions

This data set contains monthly deliveries in acre-feet of transmountain or other consumable water to the Arkansas River through the Pueblo Composite Gage for replacement of well depletions. The data are represented in a tab-delimited data set. These deliveries are included in the streamflow records used to create the Pueblo Composite Gage. To account for these deliveries in the H-I Model, the deliveries are subtracted from the Pueblo Composite Gage in both the Historical and the Compact runs. The deliveries, less the transit losses, are added to the specified river reach and transit losses are distributed when the transmountain switch is on (JTM=1).

The first value in the second row is the annual number of deliveries. The four values in the third and subsequent rows are the month of the delivery, the river reach to which the delivery was made, the monthly amount of the delivery in acre-feet at the Pueblo Composite Gage and the monthly amount of the delivery in the specified reach after subtraction of transit losses.

An example of Data Set 25 is shown below.

```
C START DATA
1
6                18                1000              850
```

3.2.1.26. Data Set 26 – Deliveries of Water through the Pueblo Composite Gage for Storage in the Great Plains Reservoirs or Lake Meredith for Non-Irrigation Use

This data set contains monthly deliveries in acre-feet of transmountain or other consumable water through the Pueblo Composite Gage for storage in the Great Plains Reservoirs or Lake Meredith for non-irrigation use. This data set facilitates calculation of canal seepage losses on such deliveries. The data are represented in a tab-delimited data set. These deliveries are not added to the storage in these reservoirs in the H-I Model because these uses are not simulated in the model. These deliveries are subtracted from the Pueblo Composite Gage in both the Historical and the Compact runs. Canal seepage is computed when the transmountain switch is on (JTM=1). If releases are made from Lake Meredith for exchange to Pueblo Reservoir or other reservoirs upstream from the H-I Model Domain, those releases are included in Data Set 22.

The first value in the second row of the data set is the annual number of deliveries. If there are no deliveries during the year, then 0 is used. The three values in the third and subsequent rows are the month of the delivery, the user receiving the delivery and the monthly amount of the delivery in acre-feet. See Data Set 23 for an example of the form and format of this data set.

3.2.1.27. Data Set 27 – LAWMA Account Deliveries to Another User in the H-I Model

This data set contains monthly deliveries in acre-feet of water from the LAWMA account in the H-I Model to an H-I Model user that are made to replace well depletions to senior surface water rights in Colorado as part of LAWMA's replacement plan. This data set is not presently used. Revisions to the H-I Model code are necessary to simulate actual return flow operation before this data set is operable.

3.2.1.28. Data Set 28 – LAWMA Account Deliveries to the River

This data set contains monthly releases in acre-feet from the LAWMA Account in the H-I Model to the Arkansas River. These releases are subtracted from the LAWMA account and added to river Reach 11 when the transmountain switch is on (JTM=1). This offsets depletions due to pumping. The data are represented in a tab-delimited data set.

The first value in the second row of this data set is the annual number of releases. If there are no releases during the year, then 0 is used. The three values in the third and subsequent rows are the month of the release, the river reach and the monthly amount of the delivery in acre-feet. See Data Set 23 for an example of the form and format of this data set.

3.2.1.29. Data Set 29 – No longer needed since the creation of the Offset Account.

3.2.1.30. Data Set 30 – Not currently used and no longer needed since the creation of the Offset Account.

3.2.1.31. Data Set 31 – Releases of Consumable Water from Lake Meredith for Delivery to the River

This data set contains monthly releases in acre-feet of consumable water from Lake Meredith for delivery to the river for replacement used to place transit losses in specific reaches.

The first value in the second row of the data set is the annual number of releases. If there are no releases during the year, then 0 is used. The four values in the third and subsequent rows are the month in which a delivery was made, the river reach to which the delivery was made, the monthly amount of the delivery at the point of release and the monthly amount of the delivery at the point of delivery after subtraction of transit losses. See Data Set 25 for an example of the form and format of this data set.

3.2.1.32. Data Set 32 – Not currently used

3.2.1.33. Data Set 33 – Undistributed Replacement Water in the WWSP Storage in Pueblo Reservoir Prior to Distribution

This data set contains monthly deliveries in acre-feet to the WWSP storage pool in Pueblo Reservoir to replace well depletions during the WWSP prior to distribution and release of the replacement water. The deliveries to the WWSP storage account occur during the WWSP season (November 15 through March 14) and are reduced by evaporation to compute the deliveries in acre-feet that are made at the end of the WWSP season.

3.2.1.34. through 3.2.1.48. Data Sets 34-48: Reserved for Future Use

3.2.1.49. Data Set 49 – Irrigated Acreage

This data set contains irrigated acreage data in acres for H-I Model users. There are 23 users currently represented in the H-I Model. User 20 was originally the Manvel Canal, but it has been combined with the Lamar Canal (User 18) and User 20 is no longer used; zeros are entered in the row for User 20 in this data set. This data set consists of an array of 24 rows by 4 columns. One row is used for each of the 23 users represented in the H-I Model; the values

in the four columns are acreages by type. The data are represented in a tab-delimited data set.

The 1st column is acreage irrigated with surface water use only.

The 2nd column is acreage irrigated with surface water and groundwater. The acreage in canal service areas that was previously irrigated with surface water and groundwater, but where the ditch capacity in the H-I Model is set to 0 because the canal no longer diverts surface water from the river is included in the 2nd column even though no surface water is diverted. These include Booth-Orchard, X-Y Graham and Sisson-Stubbs.

The 3rd column is acreage irrigated with groundwater only (sole source). Users 14 and 24 are entirely sole source groundwater. Acreage in the canal service areas of other users that have acreage irrigated with groundwater only is included in the 3rd column (except as noted above).

The 4th column is acreage that is not irrigated by surface or groundwater (dry-up) where the surface water that formerly irrigated this acreage is being used for replacement of well depletions. The dry-up acreage is included as part of the total acreage used to compute demand (WANT) for irrigation water. The water used for replacement is returned to the river in the Historical run using a spill factor or is not diverted because the ditch capacity is set to 0. The dry-up acreage is irrigated in the Compact run.

An example of Data Set 49 is below.

C START DATA			
7106	9419	2605	0
0	600	0	0
0	1940	0	0
0	722	48	0
27887	6504	909	0
16193	6297	240	0
0	4255	195	0
3662	1496	92	0
6021	9823	586	0
59500	33468	1129	0
3844	2458	67	0
11037	3297	186	0
1139	4855	6	0
0	0	1520	0
955	4070	106	749
0	1950	0	0
22583	15694	2073	0
89	8844	103	404
31	1533	46	0
0	0	0	0
0	7048	0	662
779	5716	279	0
0	360	0	0
0	0	6474	0

3.2.1.50. Data Set 50 – Potential Evapotranspiration (PET) Data

This data set contains monthly potential evapotranspiration (PET) for the 23 users in the H-I Model. The data set is derived using the Penman-Monteith equation and crop coefficients. The Penman-Monteith equation used is the final published version of the ASCE Standardized Penman-Monteith Equation for computation of alfalfa reference crop evapotranspiration (ET). Normalized crop coefficient (Kc) values submitted by Kansas at trial in 2002 and CoAgMet weather data are used with alfalfa reference ET computed using Penman-Monteith equation to compute crop PET. Pre-processing programs used as part of this procedure are found in Attachment 6.1.5. to this Appendix C.1.

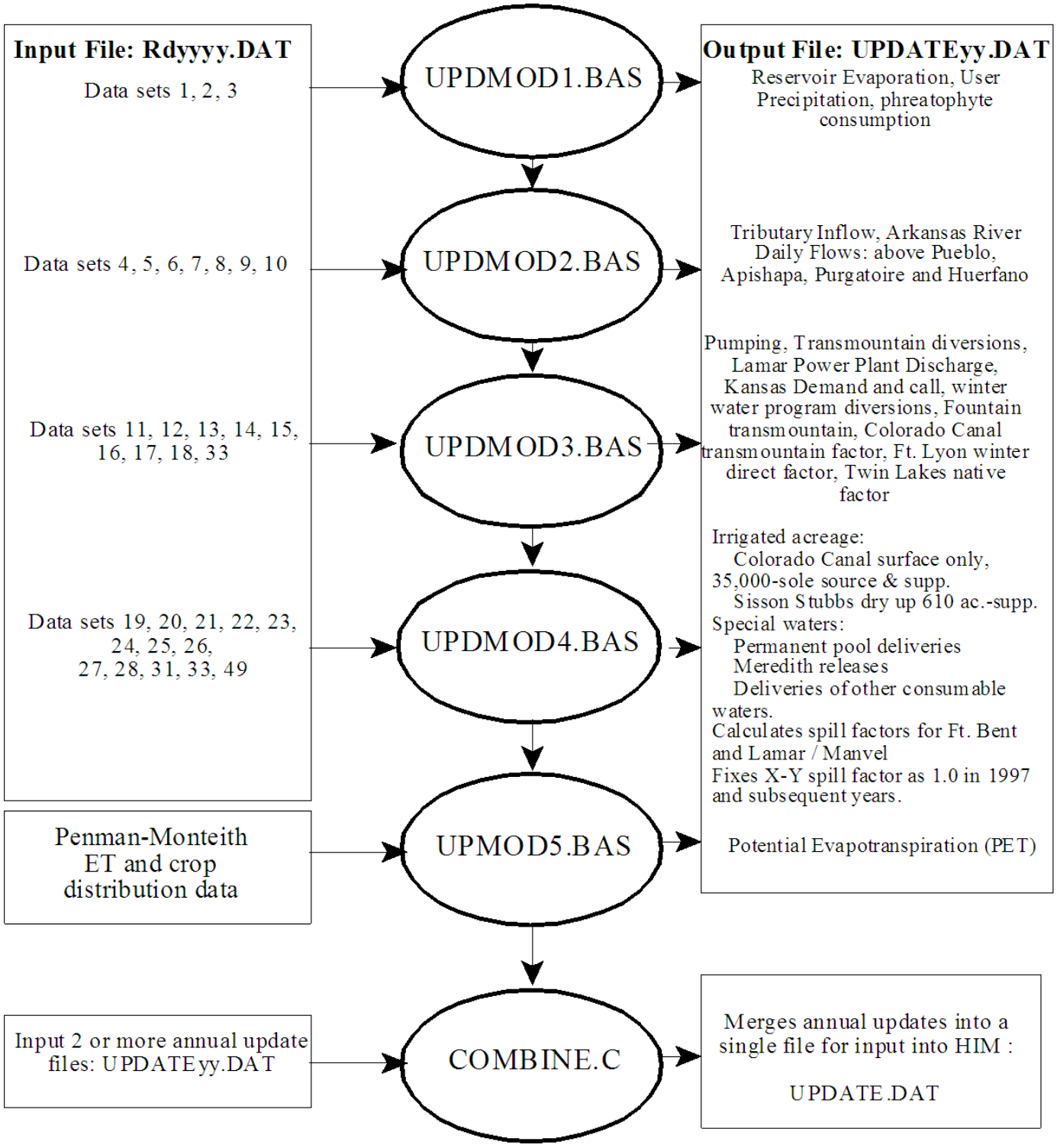

Input File: Rdyyyy.DAT
Data sets 1, 2, 3
UPDMOD1.BAS
Output File: UPDATEyy.DAT
Reservoir Evaporation, User Precipitation, phreatophyte consumption
Data sets 4, 5, 6, 7, 8, 9, 10
UPDMOD2.BAS
Tributary Inflow, Arkansas River Daily Flows: above Pueblo, Apishapa, Purgatoire and Huerfano
Data sets 11, 12, 13, 14, 15, 16, 17, 18, 33
UPDMOD3.BAS
Pumping, Transmountain diversions, Lamar Power Plant Discharge, Kansas Demand and call, winter water program diversions, Fountain transmountain, Colorado Canal transmountain factor, Ft. Lyon winter direct factor, Twin Lakes native factor
Data sets 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 31, 33, 49
UPDMOD4.BAS
Irrigated acreage:
Colorado Canal surface only, 35,000-sole source & supp.
Sisson Stubbs dry up 610 ac.-supp.
Special waters:
Permanent pool deliveries
Meredith releases
Deliveries of other consumable waters.
Calculates spill factors for Ft. Bent and Lamar / Manvel
Fixes X-Y spill factor as 1.0 in 1997 and subsequent years.
Penman-Monteith ET and crop distribution data
UPMOD5.BAS
Potential Evapotranspiration (PET)
Input 2 or more annual update files: UPDATEyy.DAT
COMBINE.C
Merges annual updates into a single file for input into HIM :
UPDATE.DAT

Figure 9. Chart of UPDATE.BAT for Annual Updates

3.3. *Data Processors*

The data sets that are part of data file Rdyyyy.DAT are processed by five BASIC programs. These five programs are arranged in a batch file, UPDATE.BAT, which creates a file named UPDATEyy.DAT (where yy are the last 2 digits in the year.) A sixth program in UPDATE.BAT merges 2 or more UPDATEyy.DAT files into UPDATE.DAT. The BASIC programs in UPDATE.BAT are named UPDMOD1.BAS, UPDMOD2.BAS, UPDMOD3.BAS, UPDMOD4.BAS, ET Updating Preprocessor and Combine.C. See Figure 9. The following narrative discusses the operation of these processing programs. The reader should refer to the previous discussion of the individual data sets to understand fully the operation of these processors.

3.3.1. UPDMOD1.BAS: Creates Update Files for Evaporation, Precipitation and Phreatophyte Consumption

This program processes Data Sets 1, 2 and 3.

3.3.1.1. Data Set 1

UPDMOD1.BAS reads the flag and the daily pan evaporation and ice cover factor from the input file Rdyyyy.DAT. If the flag indicates that the daily pan evaporation and ice cover factor values are used, the daily pan evaporation value is adjusted using the ice cover factor. For example, if the ice cover factor is 40%, the daily evaporation will be 60% of the daily

pan evaporation. The adjusted daily pan evaporation values are accumulated for each month, and the monthly adjusted pan evaporation values are multiplied by 70% to convert those values to monthly lake evaporation. The program writes the monthly lake evaporation values to output file UPDATEyy.DAT using FORTRAN format (12F9.2).

3.3.1.2. Data Set 2

UPDMOD1.BAS reads the flag from input file Rdyyyy.DAT. Depending on the flag setting, the program either projects the monthly phreatophyte consumption for each of the 18 river reaches from the 1994 values to the update year based on the 1958-1994 rate of increase or uses the unprojected 1994 values obtained from the file TREES.DAT. Monthly values in acre-feet of phreatophyte consumption for each of the 18 river reaches are written to the output file UPDATEyy.DAT using FORTRAN format (9F8.0).

3.3.1.3. Data Set 3

UPDMOD1.BAS reads the flag from input file Rdyyyy.DAT and the monthly precipitation for the six stations in Data Set 3. The program computes monthly precipitation for each user area based on an assignment of precipitation stations to users. Monthly values in hundredths of inches are written to the output file UPDATEyy.DAT using FORTRAN format (12F9.0) by user and then by month.

3.3.2. UPDMOD2.BAS: Creates Update Files for Tributary Inflows

This program processes Data Sets 4, 5, 6, 7, 8, 9 and 10 and outputs monthly tributary inflows for 46 tributary stations and daily flows for four gaged stations. UPDMOD2.BAS computes the flow of the Arkansas River at the Pueblo Composite Gage. The daily flows for the streamflow gage on Arkansas River above Pueblo, the Huerfano River, the Apishapa River and the Purgatoire River are written to output file UPDATEyy.DAT using FORTRAN format (12F8.1) by gage per day per month.

3.3.2.1. Data Set 4

UPDMOD2.BAS reads the annual precipitation for 20 stations from input file Rdyyyy.DAT. The 20 stations are described in Section 3.2.1.4. above. Ten tributary basins were defined for the rainfall-runoff model, and the annual precipitation is calculated for each tributary basin using the 20 precipitation stations and a weighting value based on Theissen polygons for each station shown in Table 1 of Attachment 6.4. See Figure 10. If a precipitation value is missing, the station weight is redistributed among the remaining stations. The annual runoff from the ten tributary basins is calculated using the following equation:

(Equation 2.0) $$R = \alpha*(P-P_o)^m$$

where R is annual runoff (inches), P is annual precipitation (inches), Po is threshold precipitation and is unique to each basin, and m are constants

unique to each basin. The values for P_o, α, and m are shown in Table 2 of Attachment 6.4. The runoff in inches is then converted to acre-feet by multiplying the runoff times the area for each basin and applying appropriate unit conversions. The area for Tributary Basin 2 is reduced by 496 square miles that contribute to the Purgatoire River above the Las Animas gage. This total runoff for each tributary basin is then distributed to the ungaged tributary subbasins used in the H-I Model based on the percentage of the area of the subbasin to the total drainage area in the basin. See Table 3 of Attachment 6.4. for the tributary basin drainage areas and the percentage of the annual runoff distributed to each tributary subbasin. See Figures 4 and 10 for the location of the tributary runoff basins used in the rainfall-runoff model.

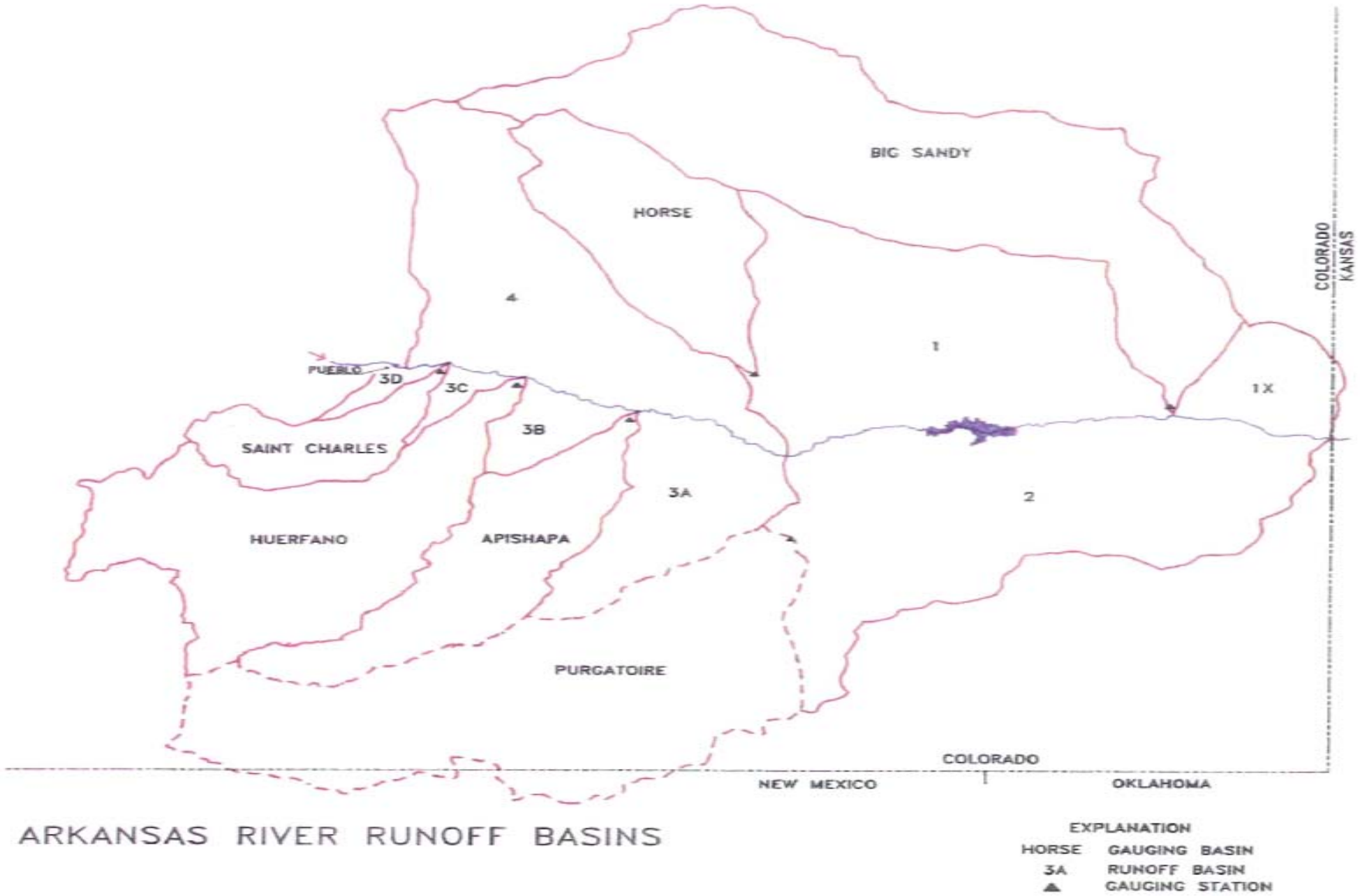


Figure 10. Runoff basins used to determine tributary inflows (From Kansas Exhibit 76A).

Once the annual runoff is calculated for each tributary subbasin used in the H-I Model, it is distributed to monthly values. The monthly distribution percentages are stored in a DATA line in the program UPDMOD2.BAS.

3.3.2.2. Data Set 5

UPDMOD2.BAS reads the monthly diversions in Data Set 5, which are used to create the monthly flow at the Pueblo Composite Gage.

3.3.2.3. Data Set 6

UPDMOD2.BAS reads Data Set 6, which contains monthly streamflows or discharges for Fountain Creek, the Pueblo waste water treatment plant, Salt Creek and the St. Charles River. The inflows from Salt Creek are the tributary inflows for Tributary Subbasin 46; the streamflows of the St. Charles River are the tributary inflows for Tributary Subbasin 43. See Figure 4.

3.3.2.4. Data Set 7

UPDMOD2.BAS reads Data Set 7, which contains the daily flows of the Apishapa River. The average monthly flows are derived from the input file SUPPLY0.DAT and stored within UPMOD2.BAS in a DATA line. The monthly flows for the Apishapa River are input to Tributary Subbasin 14. The daily flows

are used as the basis for computing the daily tributary inflow to Reach 5 in the H-I Model.

3.3.2.5. Data Set 8

UPDMOD2.BAS reads Data Set 8. The monthly flows for the Purgatoire River are input to Tributary Subbasin 23 in the H-I Model. The daily flows are used as the basis for computing the daily tributary inflow to Reach 10 in the H-I Model.

3.3.2.6. Data Set 9

UPDMOD2.BAS reads Data Set 9. The monthly flows for the Huerfano River are input to Tributary Subbasin 8 in the H-I Model. The daily flows are used as the basis for computing the daily tributary inflow to Reach 3 in the H-I Model.

3.3.2.7. Data Set 10

UPDMOD2.BAS reads Data Set 10. The monthly flows for the Arkansas River above Pueblo are used to construct the Pueblo Composite Gage, which is the inflow to Tributary Station 1. The daily flows are used as the basis for computing the daily tributary inflow for Reach 1 in the H-I Model.

3.3.3. UPDMOD3.BAS: Creates Update Files for Individual Users

This program processes Data Sets 11-18 and 33. See the previous discussion of the individual data sets for further detail regarding the operation of these processors.

3.3.3.1. Data Set 11

UPDMOD3.BAS reads the flag and monthly from the input file Rdyyyy.DAT. If the flag indicates that averages are to be used, the program computes the appropriate average monthly discharges using the input file RIGHT.DAT. The program also reads the Kansas Threshold Demands (KTD) and the Kansas Historical Calls (KHC) from RIGHT.DAT. The program writes the monthly values for the discharges from the Lamar Power Plant, KTD and KHC to output file UPDATEyy.DAT using FORTRAN format (12F9.0).

3.3.3.2. Data Set 12

UPDMOD3.BAS reads Data Set 12 from the input file Rdyyyy.DAT. The program writes the monthly conjunctive use pumping values to output file UPDATEyy.DAT using FORTRAN format (12F9.1) by user and then by month. The program writes the monthly sole source pumping values to output file UPDATEyy.DAT using FORTRAN format (12F9.1) by user and then by month.

3.3.3.3. Data Set 13

UPDMOD3.BAS reads Data Set 13 from the input file Rdyyyy.DAT. The program writes the user number and the WWSP deliveries for that user to output file UPDATEyy.DAT using FORTRAN formats (1I7) for the user number and (12F7.0) for the monthly delivery.

3.3.3.4. Data Set 14

UPDMOD3.BAS reads the flag and Data Set 14, from the input file Rdyyyy.DAT. If the flag indicates averages are to be used, the program computes the specified average monthly deliveries using input file TMOUNT.DAT. If the flag indicates that deliveries from an existing year are to be used, the program extracts that information from TMOUNT.DAT. The program writes the user number and the deliveries for that user to output file UPDATEyy.DAT using FORTRAN formats (1I7) for the user number and (12F8.1) for the monthly delivery.

3.3.3.5. Data Set 15

UPDMOD3.BAS reads Data Set 15 from the input file Rdyyyy.DAT. The program writes the flows to output file UPDATEyy.DAT using FORTRAN format (12F7.1).

3.3.3.6. Data Set 16

UPDMOD3.BAS reads the flag under Data Set 16. If the flag is set to 0, the program reads Data Set 16 from the input file Rdyyyy.DAT. If the flag indicates that the supplied daily transmountain flows are to be used, the program computes a daily transmountain diversion factor. The daily transmountain diversion factor is the daily transmountain diversion divided by the monthly transmountain deliveries from Data Set 14. The daily factors must have a monthly sum of 1.0 in months when there are transmountain deliveries and 0.0 in months when there are no transmountain deliveries. If the flag indicates averages are to be used, the program computes the specified averages using the input file TMOUNT.DAT. If the flag indicates that a previous year is to be used, the program extracts the daily values from TMOUNT.DAT and adjusts them appropriately such that the monthly sums are 1.0 or 0.0.

UPDMOD3.BAS checks Data Set 16 for compatibility. An error message is displayed on the screen if the 1.0 or 0.0 tests are not met. The program writes the month (beginning with January, 1950 as month 1) and the daily transmountain diversion factors to output file UPDATEyy.DAT using FORTRAN formats (1I4) for month number and (31F7.4) for the factors.

3.3.3.7. Data Set 17

UPDMOD3.BAS first reads the flag from the input file Rdyyyy.DAT. If the flag indicates that the

Fort Lyon winter direct-flow factors are zero, the program sets all the monthly factors to zero. If the flag indicates that the factors are to be computed, the program reads Data Set 17, which contains the daily diversions for the Fort Lyon Canal (total through the structure), the Fort Lyon Storage Canal and the Kickingbird Canal. The Fort Lyon Canal direct-flow diversions factors are computed by first calculating the Fort Lyon Canal direct-flow diversions, which are the total Fort Lyon Canal diversions minus Kickingbird Canal diversions. The Kickingbird Canal diversions are adjusted to the Fort Lyon Canal headgate by dividing the Kickingbird diversions by 0.7. The Fort Lyon Canal winter direct-flow factor is then computed for each winter month by dividing Fort Lyon Canal direct-flow winter diversions by the sum of those diversions and the diversions of the Fort Lyon Storage Canal. The factors are computed only for the period of the WWSP (November 15 to the following March 15). The program displays the factors and diversions on the screen for the choice of using the factors or rejecting them. The program writes factors to output file UPDATEyy.DAT using FORTRAN format (12F6.3).

3.3.3.8. Data Set 18

UPDMOD3.BAS reads Data Set 18 from the input file Rdyyyy.DAT. The program multiplies the monthly deliveries by the native percentage. The program writes the resultant native Twin Lakes Reservoir deliveries to the Colorado Canal to output

file UPDATEyy.DAT using FORTRAN format (12F7.1).

3.3.4. UPDMOD4.BAS: Creates List of Special Waters

This program processes Data Sets 19-32, which results in a list of special waters annually. "Special waters" are releases or deliveries not specifically or normally accounted for by the H-I Model. The releases or deliveries in the following data sets are described as "special waters," and each data set is treated in a specific fashion by the H-I Model to represent the release or delivery appropriately. UPDMOD4.BAS totals the number of releases or deliveries of each type of special water as specified below (19-32) and writes the total to UPDATEyy.DAT in FORTRAN format (1I8). For each release or delivery of a special water, the type, month, user or reach number and the amount of the release or delivery with and without transit loss are written to UPDATEyy.DAT using FORTRAN formats (3I4) for type, month, user or reach and (2F10.0) for the amounts of release (with or without transit loss).

See the previous discussion of the individual data sets for further detail about the operation of these processors.

3.3.4.1. Data Set 19

UPDMOD4.BAS reads Data Set 19. The program reads the number of deliveries, the month of the delivery, and the amount of the delivery for each delivery, from Rdyyyy.DAT. The program assigns negative signs to the amounts, sets the user or reach indices at 1, and converts the month number to the chronological number for months beginning with January, 1950, as month 1, February, 1950, as month 2, and so forth.

3.3.4.2. Data Set 20

UPDMOD4.BAS reads Data Set 20. The program reads the number of releases, the release month and the release amount for each release from Rdyyyy.DAT. The program sets the user or reach indices at 1, and converts the month number to the chronological number for months beginning with January, 1950, as month 1, February, 1950, as month 2, and so forth.

3.3.4.3. Data Set 21

UPDMOD4.BAS reads Data Set 21. The program reads the number of releases, the release month and the release amount for each release from Rdyyyy.DAT. The program assigns negative signs to the amounts, sets the user or reach indices to the reach in which the release is made, and converts the month number to the chronological number for months beginning with January, 1950, as month 1.

3.3.4.4. Data Set 22

UPDMOD4.BAS reads Data Set 22. The program reads the number of releases, the release month and the release amount for each release from Rdyyyy.DAT. The program assigns negative signs to the amounts, sets the user or reach indices to Reach 7, and converts the month number to the chronological number for months beginning with January, 1950, as month 1.

3.3.4.5. Data Set 23

UPDMOD4.BAS reads Data Set 23. The program reads the number of releases, the release month and the release amount for each release from Rdyyyy.DAT. The program assigns negative signs to the amounts, sets the user or reach indices to specified user number, and converts the month number to the chronological number for months beginning with January, 1950, as month 1.

3.3.4.6. Data Set 24

UPDMOD4.BAS reads Data Set 24. The program reads the number of releases, the release month and the release amount for each release from Rdyyyy.DAT. The program converts the month number to the chronological number for months beginning with January, 1950, as month 1.

3.3.4.7. Data Set 25

UPDMOD4.BAS reads Data Set 25. The program reads the number of deliveries, the delivery month and the delivery amount for each release at the Pueblo Composite Gage and at the point of delivery from Rdyyyy.DAT. The program sets the user or reach indices to specified destination reach, and converts the month number to the chronological number for months beginning with January, 1950, as month 1.

3.3.4.8. Data Set 26

UPDMOD4.BAS reads Data Set 26. The program reads the number of deliveries, the delivery month and the delivery amount for each release at the Pueblo Composite Gage from Rdyyyy.DAT. The program sets the user or reach indices to specified carrier number (Lake Meredith, carrier 5 or Great Plains Reservoir, carrier 10), and converts the month number to the chronological number for months beginning with January, 1950, as month 1.

3.3.4.9. Data Set 27 – Not currently used

3.3.4.10. Data Set 28

UPDMOD4.BAS reads Data Set 28. The program reads the number of deliveries, the delivery month and the delivery amount (acre-feet) for each release

from Rdyyyy.DAT. The program sets the user or reach indices to the specified river reach, and converts the month number to the chronological number for months beginning with January, 1950, as month 1.

3.3.4.11. Data Set 29 – Not Currently Used

3.3.4.12. Data Set 30 – Not Currently Used

3.3.4.13. Data Set 31

UPDMOD4.BAS reads Data Set 31, which contains monthly releases from Lake Meredith to the Arkansas River for replacement. The program reads the number of releases, the release month, the destination reach and the delivery amount (acre-feet) for each release at the point of release and at the point of delivery from Rdyyyy.DAT. The program sets the user or reach indices to the specified destination reach, and converts the month number to the chronological number for months beginning with January, 1950, as month 1.

3.3.4.14. Data Set 32 – Not Currently Used

3.3.4.15. Data Set 33

Data Set 33 contains replacement water that is delivered to the undistributed WWSP storage in Pueblo Reservoir prior to distribution and use. The deliveries to the pool occur during the WWSP season and are reduced by evaporation to compute the deliveries at the end of the winter season.

UPDMOD4.BAS and also UPDMOD3.BAS calculate replacement waters as a ratio of the total WWSP releases for irrigation from Rdyyyy.DAT. The ratios are written to UPDATEyy.BAS.

3.3.4.16. Data Set 47 – Reserved for Future Use

3.3.4.17. Data Set 48 – Reserved for Future Use

3.3.4.18. Data Set 49

UPDMOD4.BAS reads Data Set 49, which contains the irrigated acreage for each user, classified according to four acreage types. The program reads the acreage for the four acreage types for each user from Rdyyyy.DAT. The program writes the four types of acreage to UPDATEyy.DAT using FORTRAN format (4F8.1) by user and then type.

3.3.5. UPDMOD5.BAS

This program reads in Data Set 50, which contains the potential evapotranspiration (PET) for each of the 23 users in the H-I Model. UPDMOD5.BAS reads a flag from input Rdyyyy.DAT. If the flag indicates averages are to be used, then the program computes the appropriate averages using H-I Model input file PET.DAT. If PET data are supplied then UPDMOD5.BAS reads the monthly PET for each user from Rdyyyy.DAT. The program writes the PET to the UPDATEyy.DAT using FORTRAN format (12F6.3) first by user then by month.

3.3.6. Combine.C: Creation of the Update Data File

This program prepares the input file UPDATE.DAT.

The batch file UPDATE.BAT executes UPDMOD1.BAS through UPDMOD5.BAS, and creates UPDATEyy.DAT. Combine.C (a program written in C programming language) merges this file with the previous UPDATE.DAT to create the new UPDATE.DAT. The program writes a comment to UPDATE.DAT describing the updated time period, and the year of the update (input from the keyboard) is written in the second record using FORTRAN format (1I10).

The H-I Model program reads and uses the year to determine the number of additional months to be updated.

4. H-I Model Outputs and Post-Processing Programs and Spreadsheets

4.1. *H-I Model Outputs*

H-I Model output files are listed below in Table 4. Separate sets of H-I Model output files are generated for the Historical and Compact runs.

Table 4. H-I Model Outputs

No.	File Name	Description
1	BUDGET.OT2	Water budget, Overall cumulative mass balance for each timestep including inflows, outflows, change in storage and computed residual.
2	CALI B.OT1	Predicted monthly streamflows at each reach for each timestep.
3	DIVRSN.OT1	Predicted diversions and reservoir releases for each timestep.
4	GET.OT1	Listing of input parameters for users (reach, water rights, capacity and reservoir) Transmountain deliveries, winter water deliveries and Purgatoire River inflows
5	GET.OT2	Cumulative mass balance for all users (combined) for each timestep.
6	GWFLOW.OUT	Sum of surface water and groundwater responses for each user. Cumulative groundwater mass balance for each timestep.
7	JMRDAY.OUT	Daily accounting for John Martin Reservoir.
8	LAND.OT1	Irrigation parameters for users (Irrigated area, efficiency, return flow parameters, and soil moisture parameters)
9	LAND.OT2	Cumulative mass balance variables from Subroutine LAND for all users (combined) for each timestep.
10	LAND.OT3	Monthly Budget from Subroutine LAND for each user.
11	ROUTE.OT2	Cumulative river mass balance for all reaches for each timestep.
12	ROUTE.OT3	Monthly diversions by river reach.
13	SLFLOW.OT1	Computed streamflow at Stateline
14	SPILL.OUT	Spills from John Martin Accounts
15	STORE.OT1	Monthly reservoir, Article III and 1980 account storage.
16	SUPPLY.OT1	Total study period inflows for composite gage and each tributary. Average annual tributary inflow, phreatophyte consumption and precipitation.
17	UPDATE.OUT	Listing of inputs from Update.dat

4.2. *Post-Processing Programs and Spreadsheets*

There are several post-processing programs and spreadsheets that use H-I Model output files to produce results that are used to determine Compact compliance by Colorado with respect to groundwater pumping.

The outputs from the H-I Model include Stateline flows for each month for the Historical and Compact runs. The Durbin usable flow method with the Larson coefficients, as described in Appendix C.2 of this Decree, is used to determine whether there are accretions or depletions to Usable Stateline Flow.

4.2.1. Creating Annual Water Budgets

ANNBUDyy.BAS is a BASIC program that post-processes the monthly water budget output file land.ot3. The program creates the landbud.out file, which summarizes the annual canal water budgets for each of the 23 H-I Model users. To run the ANNBUDyy.BAS program, the BASIC code is edited at line 10 to set the path to the input file and at line 32 to set the path to the output file.

4.2.2. Summarizing the Annual Canal Water Budget Information

ANNBUDyy.WK4 is a Lotus© program that summarizes the annual canal water budget information contained in the landbud.out file from the

ANNBUDyy.BAS program. It also computes the difference between two landbud.out files. One file is imported to cell B12 in the "base run" sheet. The other file is imported into the "test run" sheet. The titles in cells B4 and B5 to these sheets are changed.

4.2.3. Creating the Monthly Budget Output Files

MONBUDyy.BAS is a BASIC program that post-processes the monthly water budget output file (land.ot3). The basic program creates the landyy files, which are monthly water budget output files for each of the 23 H-I Model users. The landyy.out files may be imported and summarized in USERDEPLN. WK4 spreadsheets. See section 4.2.4 below. To run the MONBUDyy.BAS program, the BASIC code is edited at line 15 to set the path to the input file and at line 46 to set the path to the output file. Note that the output file names are created automatically.

4.2.4. Summarizing the Monthly Water Budget for Specific Users

USERDEPLN.WK4 is a Lotus© spreadsheet that summarizes the monthly water budget for a specific H-I Model user. It is necessary to first run the MONBUDyy.BAS file to create the landyy.out files. The landyy.out file is imported to cell A1 on the "budget" sheet. The monthly water budget for each canal is the combined budget for surface water only, groundwater only and conjunctive use (mixed) irrigated areas.

5. H-I Model Calibration

The Historical run of the H-I Model is calibrated to predict diversions and streamflows. Predicted diversions and streamflows are compared to actual (observed) diversions and streamflows, and certain parameters are adjusted to calibrate the H-I Model. The primary targets used for calibration are diversions by H-I Model users and streamflows of the Arkansas River at Las Animas and at the Stateline. This narrative describes the calibration procedure and the calibration period that is used to calibrate the H-I Model. The calibration programs summarize the predicted and observed values at selected Arkansas River stream gages and for H-I Model users for the Historical run of the H-I Model. The input files must be located in the directories specified in the OPEN statements of the FORTRAN program file. The POST.BAT file is used to run all the FORTRAN calibration programs.

5.1. *Calibration Programs*

5.1.1. Stream.exe/Stream.for

This program summarizes the predicted and observed monthly streamflows at selected Arkansas River stream gages for a run of the H-I Model.

5.1.1.2. Input Files: The following is a list of input files:

(1) calib.ot1

(2) gwflow.ot2

(3) divrsn.ot1

(4) reach1.obs

(5) reach3.obs

(6) reach 5.obs

(7) reach7.obs

(8) reach9.obs

(9) reach10.obs

(10) reach13.obs

(11) reach 16.obs

(12) reach18.obs

(13) adjust.dat

(14) RIGHT.DAT

5.1.1.3. Output File: Stream.out

The stream.out file is imported for statistical analysis in the Stream. xls spreadsheet.

5.1.1.4. Stream.xls

Stream.xls is a Microsoft Excel© spreadsheet to summarize the stream.out file. The spreadsheet computes two statistics for each set of predicted and observed data over various periods. The two statistics are (a) the ratio of the predicted to the observed flows, and (b) the correlation coefficient. Summary tables are located at the bottom of the first sheet. See Attachment 6.5. for the months excluded as outlier months.

5.1.2. Diverts.exe/Diverts.for

This program summarizes the predicted and observed monthly total diversions (a) upstream of John Martin Reservoir (JMR) and (b) downstream of JMR for a run of the H-I Model.

5.1.2.1. Input files

(1) divrsn.ot1

(2) divrsn.dat

(3) gwflow.ot2

5.1.2.2. Output File: diverts.out. The diverts.out file is imported for statistical analysis in the DIVERTS.xls spreadsheet.

5.1.2.3. Diverts.xls is a Microsoft Excel© spreadsheet to summarize the diverts.out file. The spreadsheet

computes two statistics for each set of predicted and observed data over various periods. The two statistics are (a) the ratio of the predicted to the observed flows, and (b) the correlation coefficient. Summary tables are located at the bottom of the first sheet.

5.1.3. Divert.exe/Divert.for

This program summarizes the predicted and observed monthly diversions for the larger Arkansas River canals.

5.1.3.1. Input Files

(1) divrsn.ot1

(2) divrsn.dat

(3) gwflow.ot2

(4) kick.dat

5.1.3.2. Output File: divert.out. The divert.out file is imported for statistical analysis in the DIVERT.xls spreadsheet.

5.1.3.3. Divert.xls is a Microsoft Excel© spreadsheet to summarize divert.out file. The spreadsheet computes two statistics for each set of predicted and observed data over various periods. The two statistics are (a) the ratio of the predicted to the observed flows, and (b) the correlation coefficient. Summary tables

are located at the bottom of the first sheet.

5.1.4. Divert2.exe/Divert2.for. This program summarizes the predicted and observed monthly total diversions (a) upstream of John Martin Reservoir (JMR) and (b) downstream of JMR for a run of the H-I Model.

5.1.4.1. Input files

(1) divrsn.ot1

(2) divrsn.dat

5.1.4.2. Output File: divert2.out. The divert2.out file is imported for statistical analysis in the Divert2. xls spreadsheet.

5.1.4.3. Divert2.xls is a Microsoft Excel© spreadsheet to summarize divert2.out file. The spreadsheet computes two statistics for each set of predicted and observed data over various periods. The two statistics are (a) the ratio of predicted to the observed flows, and (b) the correlation coefficient. Summary tables are located at the bottom of the first sheet.

5.1.5. Store.exe/Store.for. This program summarizes the predicted and observed end-of-month (EOM) storage for each of the reservoirs simulated in the H-I Model.

5.1.5.1. Input Files

(1) store.ot1

(2) mlyresr.dat

5.1.5.2. Output File: store.out. The store.out file is imported for statistical analysis in the Store.xls spreadsheet.

5.1.5.3. Store.xls is a Microsoft Excel© spreadsheet to summarize the store.out file. The spreadsheet computes two statistics for each set of predicted and observed EOM storage for the reservoirs simulated over various periods of time. The two statistics are (a) the ratio of the predicted to the observed flows, and (b) the correlation coefficient. Summary tables are located at the bottom of the first sheet.

5.2. *Parameter Values Adjusted during Calibration*

The calibration process is used to determine the values for SEV, WTFACT and WTADD. The values are derived through an iterative process by comparing the observed and predicted streamflows and diversions for the calibration period, 1950-1994.

Values for SEV are derived by selecting values that result in the mean monthly predicted flows at

the Stateline and Las Animas matching the observed flows at those locations as closely as possible. SEV values were derived for the upstream and downstream canals. Values used in calibrations of various versions of the H-I Model are listed below:

Table 5. SEV Values Used in Approved Calibrations of H-I Model

Model Version	Submittal Date	Upstream	Downstream	Fort Lyon	Comments
Replacement Model	1991	25.0%	10.0%	10.0%	Recalibrated with variable monthly factors
For years 1986-1994	1996	25.0%	25.0%	25.0%	Recalibrated for Max Farm Efficiency
For years 1995-1996	1998	25.0%	25.0%	25.0%	
For years 1997-2004	2007	24.0%	11.0%	24.0%	Calibrated to original observed diversions
For 2005-2006 & subsequent years (unless changed as provided in the Decree)	2007	24.0%	11.0%	24.0%	Calibrated to revised observed diversions

6. Attachments

6.1. *DVD (In Pocket to Volume III)*

6.1.1. Directory of Files on DVD

6.1.2. [Reserved]

6.1.3. H-I Model Code

6.1.4. H-I Model Input Files

6.1.5. Pre-Processing Programs and Input Files

6.1.6. Post-Processing Programs

6.1.7. Calibration Programs and Data

6.1.8. Usable Flow Programs

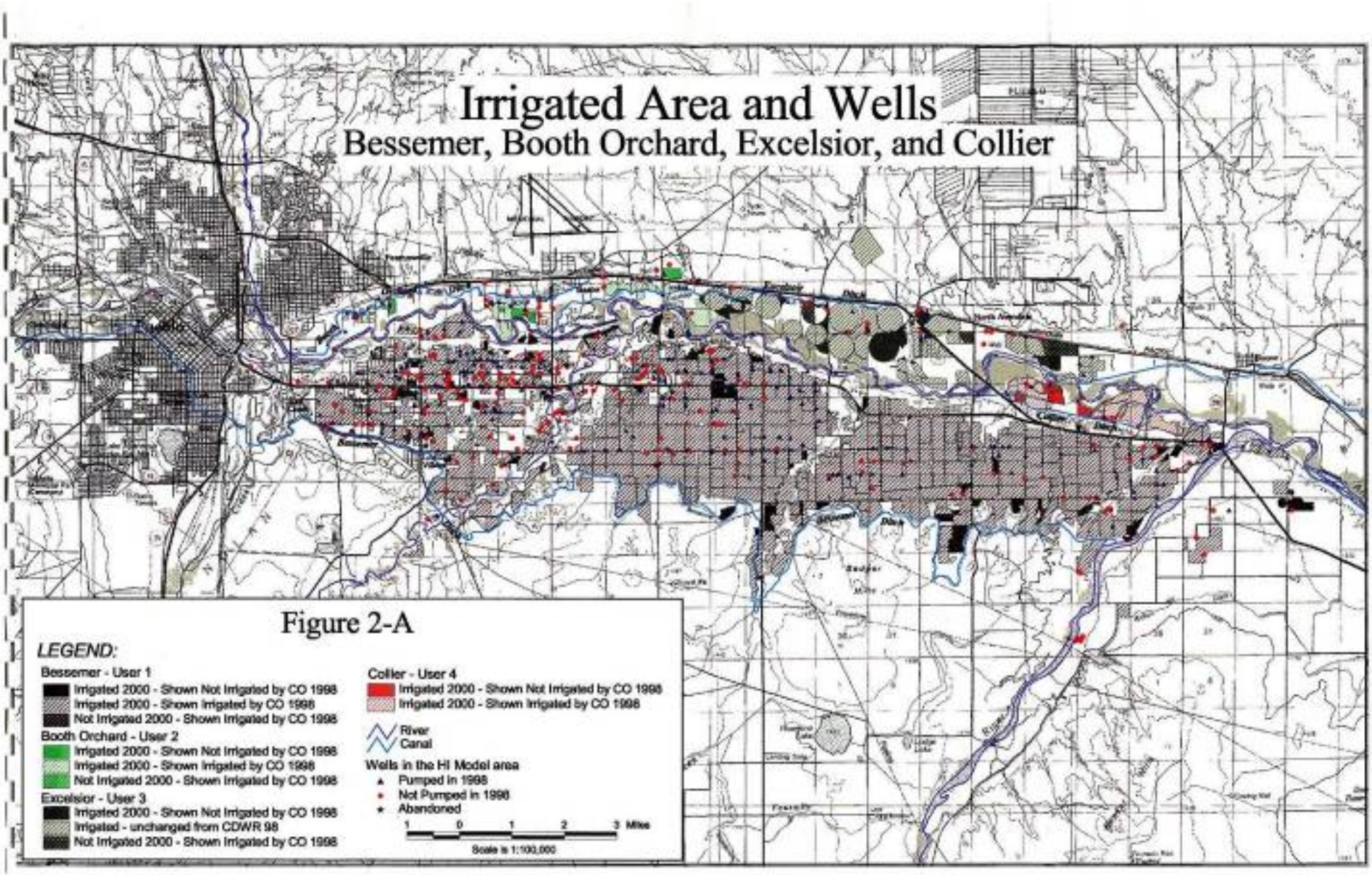
6.1.9. H-I Model Output Files

6.1.10. H-I Model Logical Flow Charts

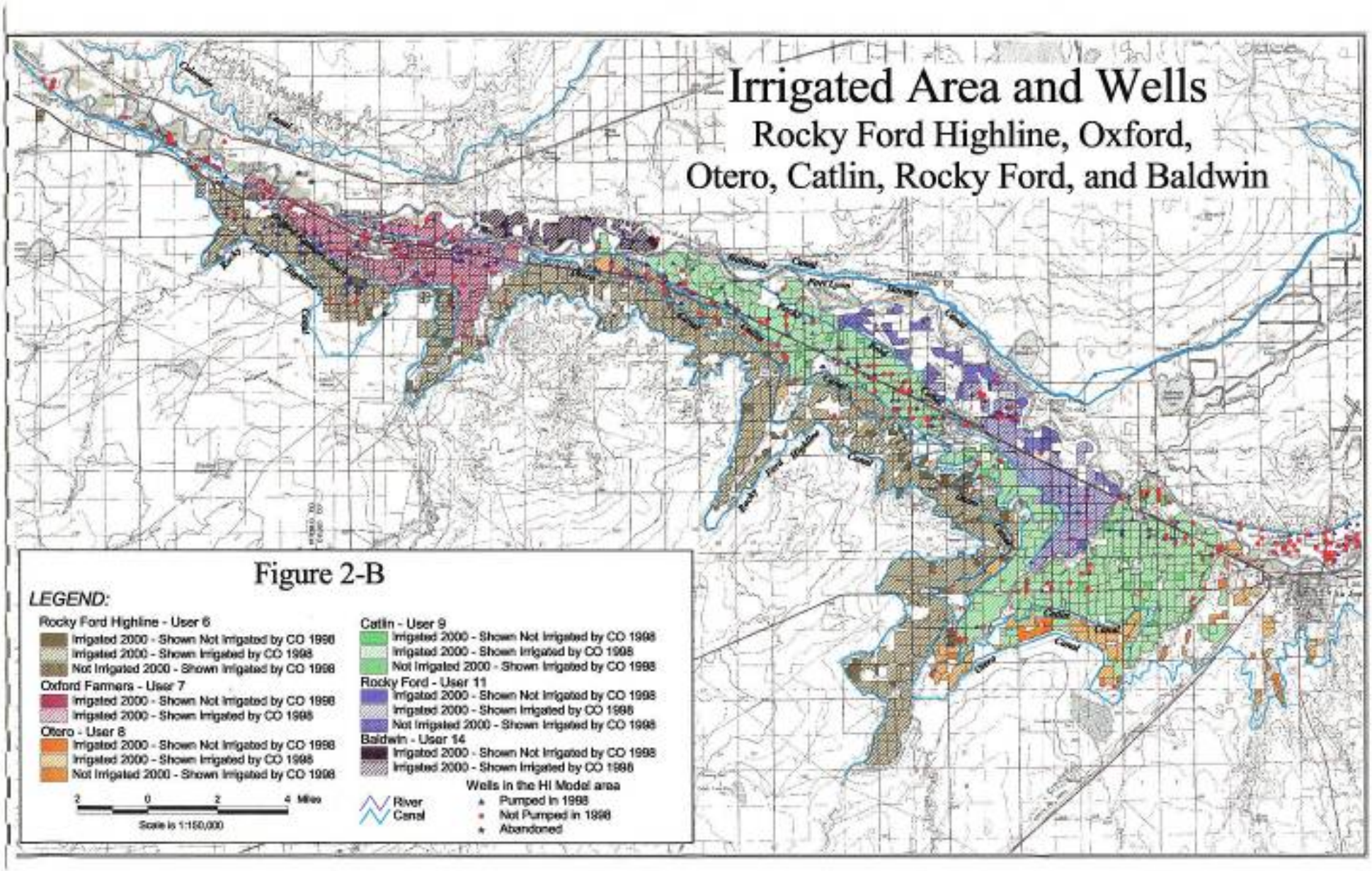
6.2. *Maps of Irrigated Areas and Wells.*

From Kansas Exhibit 1093.

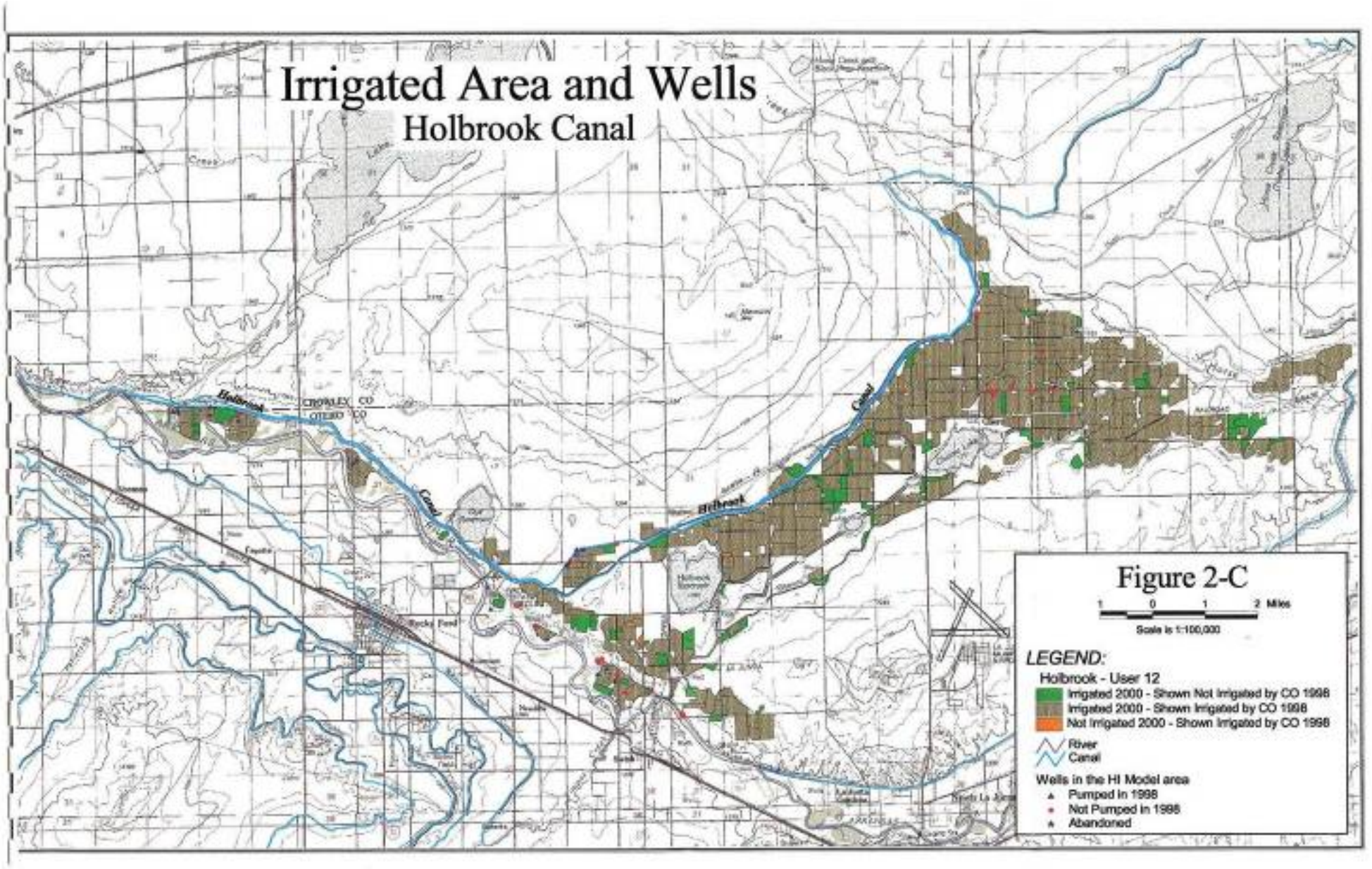
6.2.1. Maps: Irrigated Areas and Wells: Bessemer, Booth Orchard, Excelsior and Collier


Irrigated Area and Wells
Bessemer, Booth Orchard, Excelsior, and Collier
Figure 2-A
LEGEND:
Bessemer - User 1
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
Booth Orchard - User 2
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
Excelsior - User 3
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated - unchanged from CDWR 98
Not Irrigated 2000 - Shown Irrigated by CO 1998
Collier - User 4
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
River
Canal
Wells in the HI Model area
Pumped in 1998
Not Pumped in 1998
Abandoned
1 0 1 2 3 Miles
Scale is 1:100,000

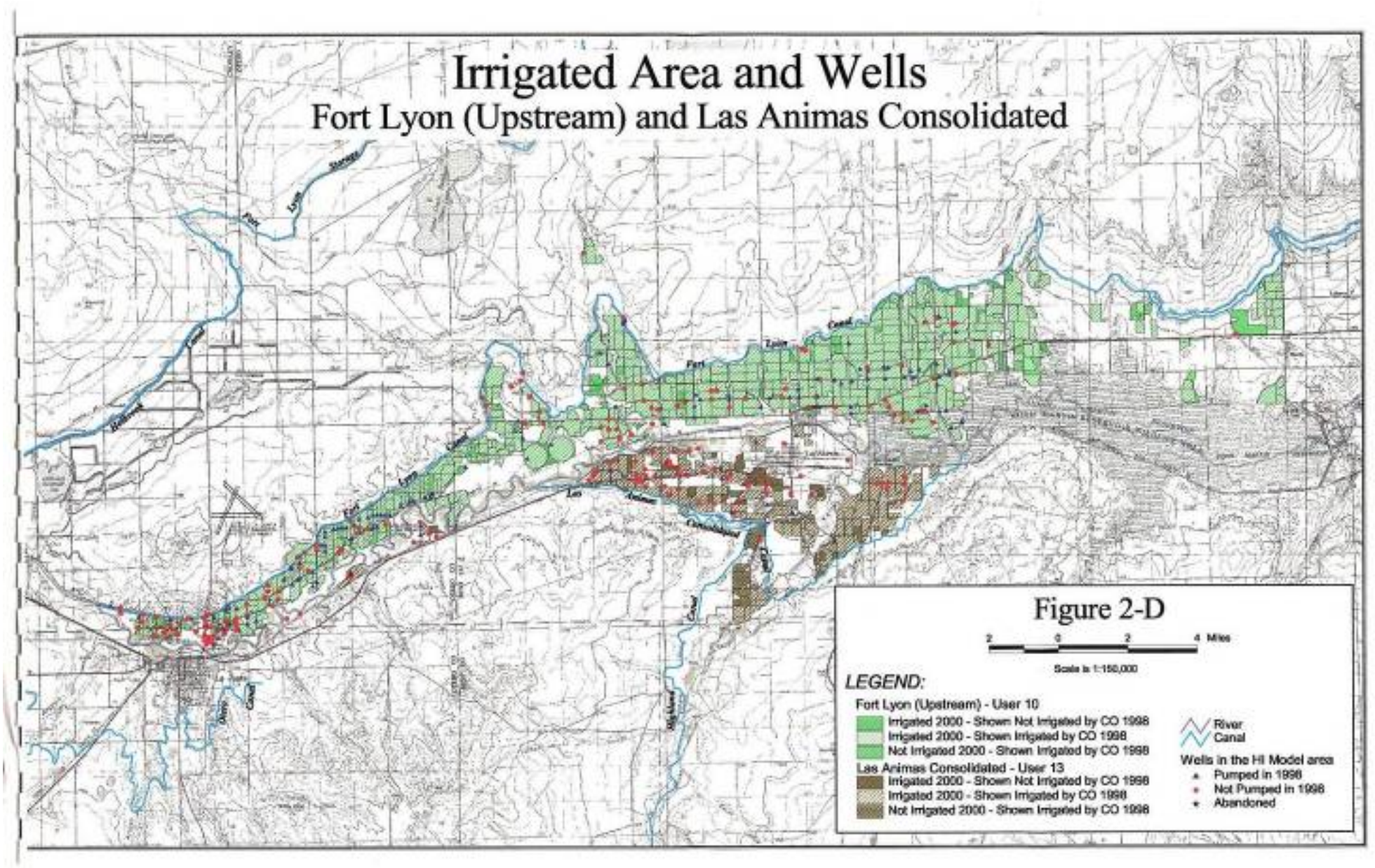
6.2.2. Rocky Ford Highline, Oxford, Otero, Catlin, Rocky Ford, and Baldwin (User 14 – Groundwater Only)


Irrigated Area and Wells
Rocky Ford Highline, Oxford,
Otero, Catlin, Rocky Ford, and Baldwin
Figure 2-B
LEGEND:
Rocky Ford Highline - User 6
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
Oxford Farmers - User 7
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Otero - User 8
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
2 0 2 4 Miles
Scale is 1:150,000
Catlin - User 9
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
Rocky Ford - User 11
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
Baldwin - User 14
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
River
Canal
Wells in the HI Model area
Pumped in 1998
Not Pumped in 1998
Abandoned

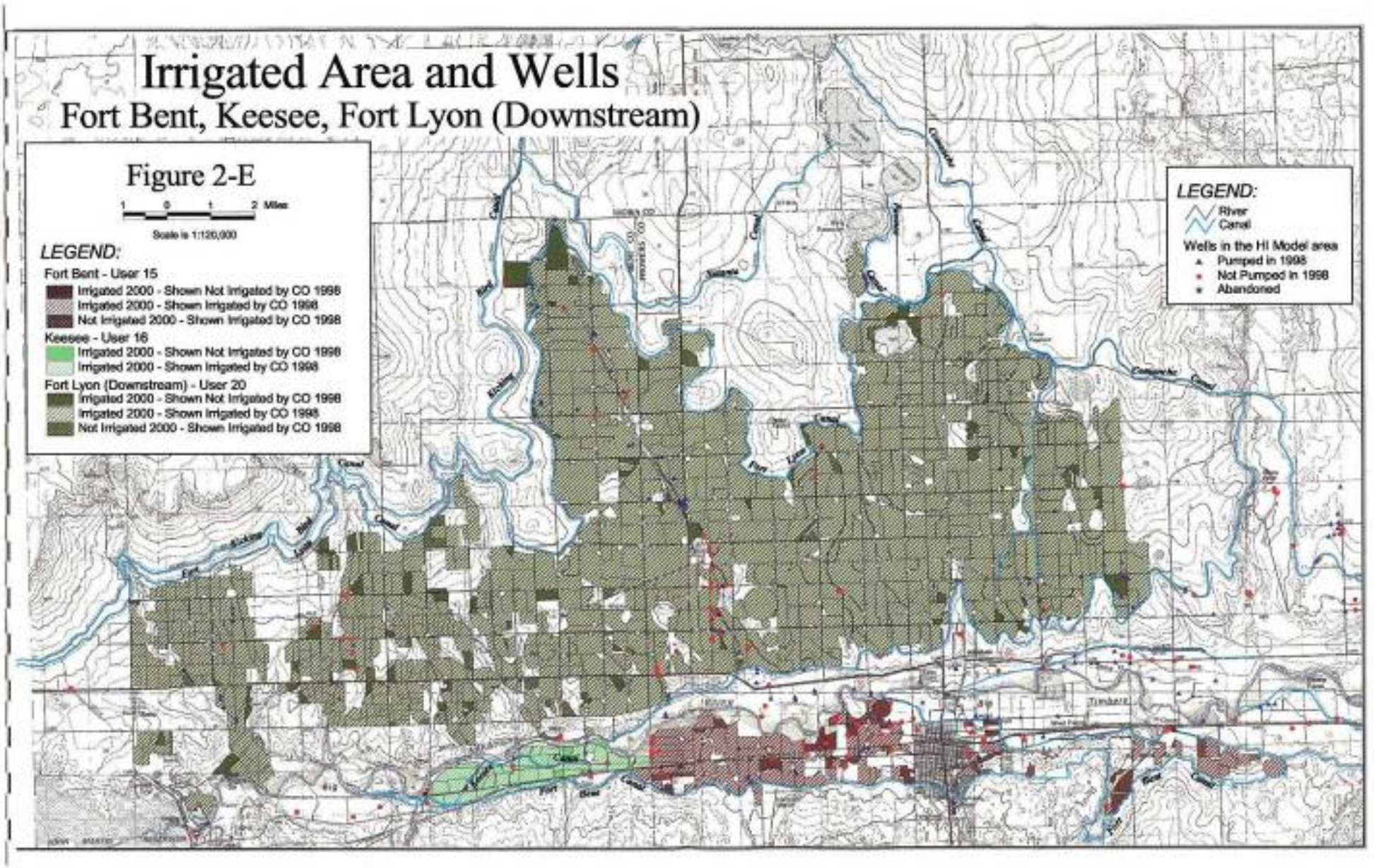
6.2.3. Holbrook Canal



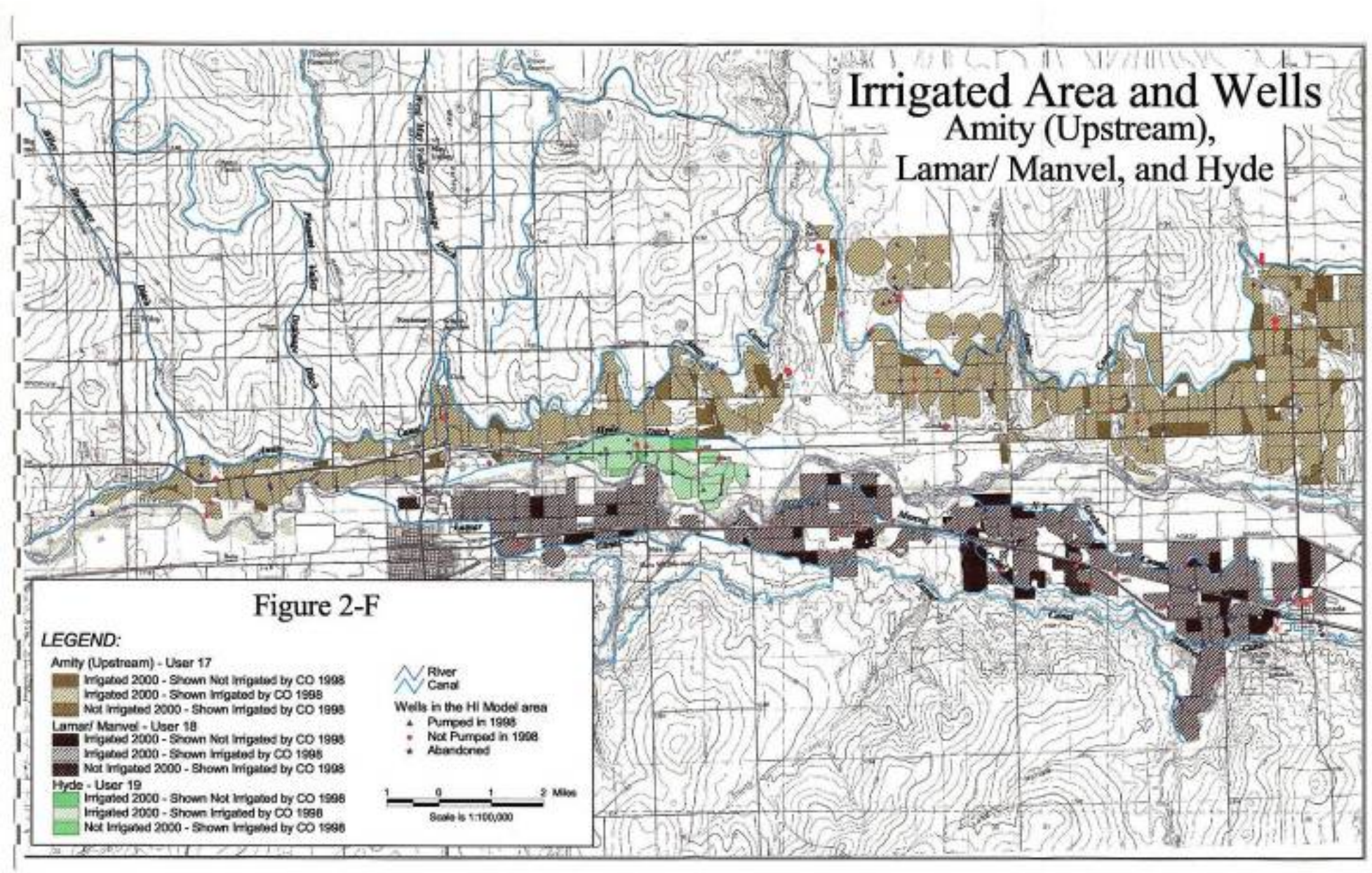
6.2.4. Fort Lyon (Upstream) and Las Animas Consolidated


Irrigated Area and Wells
Fort Lyon (Upstream) and Las Animas Consolidated
Figure 2-D
2 0 2 4 Miles
Scale is 1:150,000
LEGEND:
Fort Lyon (Upstream) - User 10
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
Las Animas Consolidated - User 13
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
River
Canal
Wells in the HI Model area
Pumped in 1998
Not Pumped in 1998
Abandoned

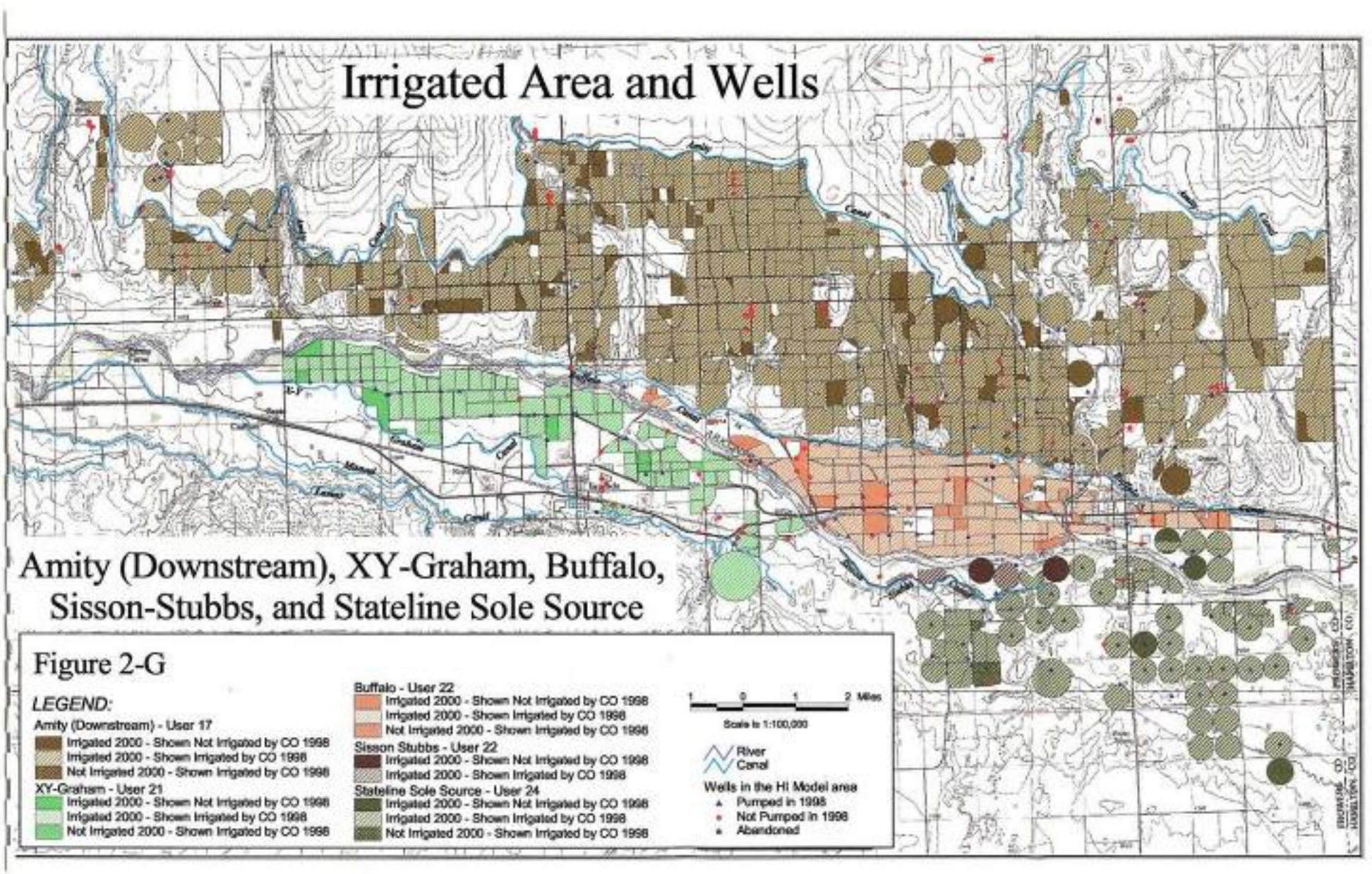
6.2.5. Fort Bent, Keesee, Fort Lyon (Downstream)


Irrigated Area and Wells
Fort Bent, Keesee, Fort Lyon (Downstream)
Figure 2-E
1 0 1 2 Miles
Scale is 1:120,000
LEGEND:
Fort Bent - User 15
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
Keesee - User 16
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Fort Lyon (Downstream) - User 20
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
LEGEND:
River
Canal
Wells in the HI Model area
Pumped in 1998
Not Pumped in 1998
Abandoned

6.2.6. Amity (Upstream), Lamar/Manvel and Hyde


Irrigated Area and Wells
Amity (Upstream),
Lamar/ Manvel, and Hyde
Figure 2-F
LEGEND:
Amity (Upstream) - User 17
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
Lamar/ Manvel - User 18
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
Hyde - User 19
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
River
Canal
Wells in the Hi Model area
Pumped in 1998
Not Pumped in 1998
Abandoned
1 0 1 2 Miles
Scale is 1:100,000

6.2.7. Amity (Downstream), X-Y Graham, Buffalo, Sisson-Stubbs, and Stateline Sole Source


Irrigated Area and Wells
Amity (Downstream), XY-Graham, Buffalo, Sisson-Stubbs, and Stateline Sole Source
Figure 2-G
LEGEND:
Amity (Downstream) - User 17
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
XY-Graham - User 21
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
Buffalo - User 22
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
Sisson Stubbs - User 22
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Stateline Sole Source - User 24
Irrigated 2000 - Shown Not Irrigated by CO 1998
Irrigated 2000 - Shown Irrigated by CO 1998
Not Irrigated 2000 - Shown Irrigated by CO 1998
1 0 1 2 Miles
Scale is 1:100,000
River
Canal
Wells in the HI Model area
Pumped in 1998
Not Pumped in 1998
Abandoned

6.3. *List of Colorado Water Rights*

Colorado Water Rights Represented in the H-I Model

Direct Flow Rights	User #	Reach #	Water Right (cfs)	Appropriation Date
Booth Canal	2	1	7.00	04-00-1861
Bessemer Ditch	1	1	2.00	04-30-1861
Bessemer Ditch	1	1	20.00	12-31-1861
Rocky Ford Highline	6	3	40.00	12-31-1861
Booth Canal	2	1	8.00	04-01-1864
Bessemer Ditch	1	1	3.74	05-31-1864
Bessemer Ditch	1	1	3.00	06-30-1866
Bessemer Ditch	1	1	2.50	01-08-1867
Bessemer Ditch	1	1	5.13	05-31-1867
Rocky Ford Highline	6	3	0.60	09-01-1867
Oxford Farmers Ditch	7	4	13.40	09-01-1867
Rocky Ford Highline	6	3	16.00	07-01-1869
Bessemer Ditch	1	1	1.47	11-30-1870
Bessemer Ditch	1	1	3.40	12-31-1870
Keesee Ditch	16	11	9.00	03-31-1871
Booth Canal	2	1	1.00	00-00-1871
Bessemer Ditch	1	1	2.00	09-18-1873
Rocky Ford Canal	11	6	111.76	05-15-1874
Lamar Ditch	18	13	15.75	11-30-1875
Bessemer Ditch	1	1	3.00	12-31-1876
Bessemer Ditch	1	1	0.41	12-31-1878
Bessemer Ditch	1	1	14.00	05-04-1881
Booth Canal	2	1	2.00	00-00-1881
Bessemer Ditch	1	1	2.00	06-20-1881
Bessemer Ditch	1	1	8.00	03-31-1882
Keesee Ditch	16	11	4.50	12-31-1883
Rocky Ford Highline	6	3	0.00	03-07-1884
Las Animas Consolidated	13	8	38.00	03-07-1884
Fort Lyon Canal	10	7	164.64	04-15-1884
Catlin Canal	9	5	248.00	12-03-1884
Las Animas Consolidated	13	8	44.30	12-03-1884
Buffalo Canal	22	16	67.50	01-29-1885
Rocky Ford Highline	6	3	30.00	06-30-1885
Rocky Ford Highline	6	3	2.00	03-11-1886
Fort Bent Canal	15	11	27.77	04-01-1886
Lamar Ditch	18	13	72.09	11-04-1886
Amity Canal	17	12	283.50	02-21-1887
Oxford Farmers Ditch	7	4	116.00	02-26-1887
Fort Lyon Canal	10	7	597.16	03-01-1887

Colorado Water Rights Represented in the H-I Model (cont.)

Direct Flow Rights	User #	Reach #	Water Right (cfs)	Appropriation Date
Collier Ditch	4	2	4.00	03-10-1887
Lamar Ditch	18	13	13.64	04-16-1887
Bessemer Ditch	1	1	322.00	05-01-1887
Excelsior Ditch	3	1	20.00	05-01-1887
Collier Ditch	4	2	22.00	05-01-1887
Hyde Canal	19	14	23.44	05-10-1887
Catlin Canal	9	5	97.00	11-14-1887
Las Animas Consolidated	13	8	80.00	03-13-1888
Booth Canal	2	1	2.10	03-30-1888
Fort Bent Canal	15	11	32.77	03-10-1889
X-Y Graham Canal	21	15	69.00	07-22-1889
Fort Bent Canal	15	11	11.70	09-11-1889
Holbrook Canal	12	6	155.00	09-25-1889
Rocky Ford Highline	6	3	2.50	01-06-1890
Excelsior Ditch	3	1	40.00	01-06-1890
Rocky Ford Highline	6	3	378.00	01-06-1890
Otero Canal	8	4	123.00	03-03-1890
Rocky Ford Canal	11	6	96.54	05-06-1890
Colorado Canal	5	2	756.28	06-09-1890
Lamar Ditch	18	13	184.27	07-16-1890
Fort Bent Canal	15	11	26.77	08-12-1890
Manvel/Lamar Canal	18	13	54.00	10-14-1890
X-Y Graham Canal	21	15	61.00	08-24-1891
Sisson & Stubbs Ditch	23	17	18.00	12-01-1891
Fort Bent Canal	15	11	50.00	01-01-1893
Amity Canal	17	12	500.00	04-01-1893
Booth Canal	2	1	3.20	04-15-1893
Holbrook Canal	12	6	445.00	08-30-1893
Fort Lyon Canal	10	7	171.20	08-31-1893
Keesee Ditch	16	11	15.00	09-03-1893
Sisson & Stubbs Ditch	23	17	7.20	12-01-1895
Booth Canal	2	1	7.00	00-00-1894
Fort Bent Canal	15	11	80.00	12/31/1900
Otero Canal	8	4	334.92	2/2/1903
Las Animas Consolidated	13	8	44.80	4/15/1909

Colorado Water Rights Represented in the H-I Model (cont.)

Storage Rights	User #	Reach #	Water Right (Ac-Ft)	Appropriation Date
Lake Henry	26	2	6,353	12-31-1891
Holbrook Reservoir	29	6	4,276	03-02-1892
Great Plains Reservoirs	30	7	223,221	08-01-1896
Lake Meredith	27	2	26,028	03-09-1898
Dye Reservoir	28	6	4,500	10/10/1903
Horse Creek Reservoir	31	6	26,887	1/25/1906
Adobe Creek Reservoir	32	6	61,575	1/25/1906
Horse Creek Reservoir	31	6	1,113	6/12/1908
Adobe Creek Reservoir	32	6	25,425	12/29/1908
Lake Henry	26	2	3,561	6/15/1909
Dye Reservoir	28	6	3,486	9/3/1909
Holbrook Reservoir	29	6	3,196	9/15/1909

6.4. ***Areas Tributary to H-I Model Domain (Figure 4) and Tables Related to the Rainfall-Runoff Model***

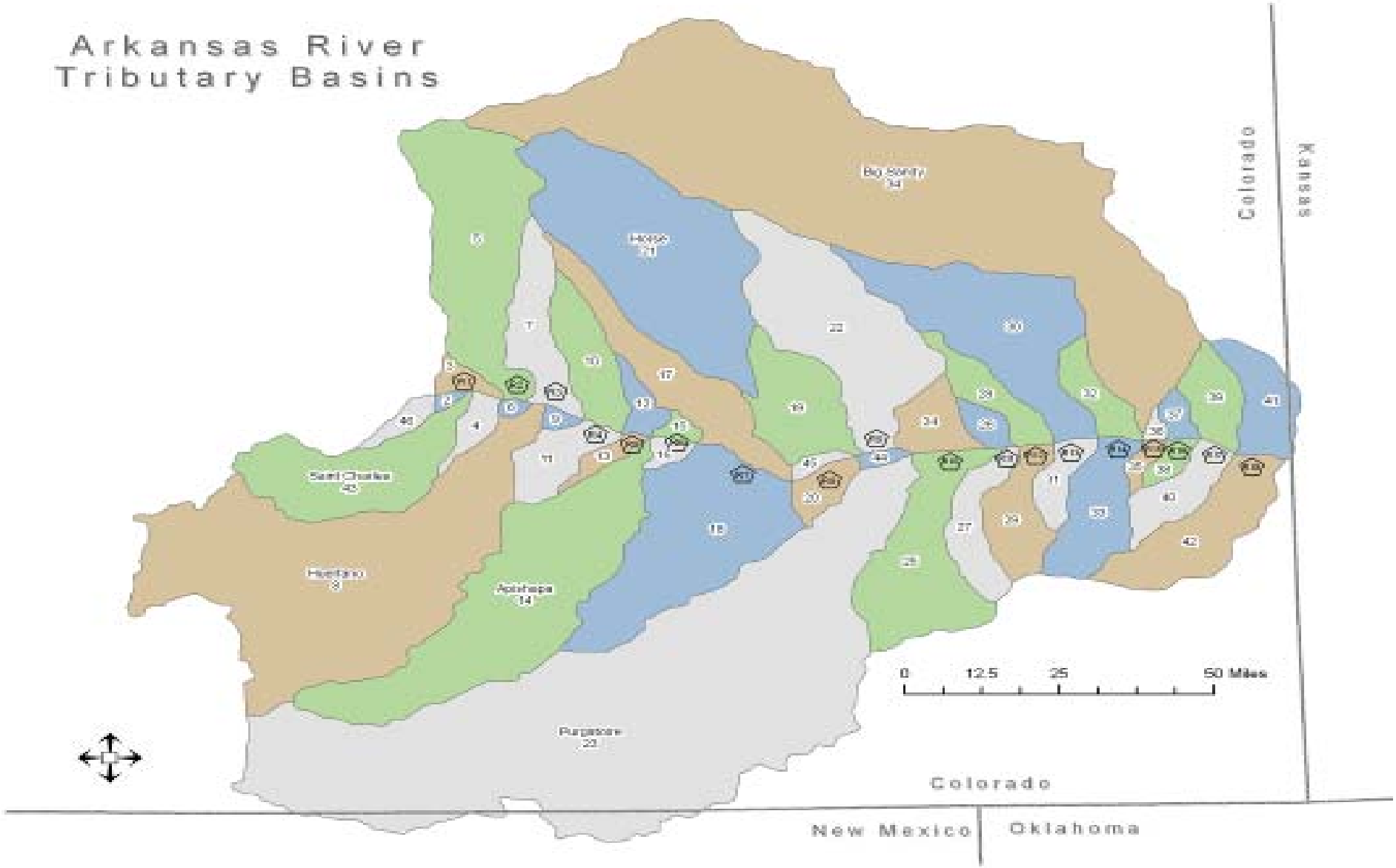


Table 1. Precipitation Weights		
Tributary Runoff Basin	**Precipitation Station**	**Weight**
1	Karval	0.13%
	Haswell	40.09%
	Lamar	12.72%
	John Martin Dam	11.28%
	Las Animas	12.19%
	La Junta	4.50%
	Rocky Ford	2.60%
	Ordway	6.18%
1X	Cheyenne Wells	38.54%
	Holly	45.85%
	Lamar	15.61%
2	Timpas	9.90%
	La Junta	10.03%
	Las Animas	12.59%
	John Martin Dam	14.78%
	Lamar	18.11%
	Holly	8.12%
	Walsh	1.75%
	Springfield	24.70%
3A	Rocky Ford	22.75%
	La Junta	7.62%
	Timpas	65.50%
	Aguilar	4.13%
3B	Tacony	32.75%
	Ordway	5.27%
	Rocky Ford	25.60%
	Timpas	21.71%

Table 1. Precipitation Weights (cont.)		
Tributary Runoff Basin	**Precipitation Station**	**Weight**
	Walsenburg	3.25%
	Pueblo	11.42%
3C	Pueblo	96.83%
	Tacony	3.17%
3D	Pueblo	100.00%
4	Colorado Springs	11.08%
	Fountain	24.71%
	Pueblo	10.11%
	Tacony	36.15%
	Ordway	13.75%
	Rocky Ford	3.31%
	La Junta	89.00%
Horse Creek	Colorado Springs	1.22%
	Limon	6.5800%
	Karval	37.18%
	Ordway	14.53%
	Tacony	31.64%
	Fountain	8.85%
Big Sandy	Colorado Springs	1.72%
	Limon	29.26%
	Karval	27.01%
	Cheyenne Wells	22.40%
	Haswell	12.17%
	Lamar	7.44%

Table 2. Runoff Equation Constants			
Tributary Runoff Basin	**α**	**P_o**	**m**
1, 1X, 2, 3A, 3B, 3C, 3D, 4, Horse	.00097183	3.983806	1.749606
Big Sandy	2.55E-06	4.964419	3.950173

Table 3. Runoff Basin Area and Tributary Basin Weight			
Tributary Runoff Basin	**Area (mi^2)**	**Tributary Subbasin**	**Percentage**
1	2606	19	14.70%
		22	33.30%
		24	6.30%
		26	2.00%
		28	6.90%
		30	29.50%
		32	5.90%
		45	1.30%
1X	498	36	4.00%
		37	11.70%
		39	37.10%
		41	47.20%
2	2959	20	3.20%
		25	21.00%
		27	8.10%
		29	8.90%
		31	4.10%
		33	11.40%
		35	1.60%
		38	2.10%

Table 3. Runoff Basin Area and Tributary Basin Weight (cont.)			
Tributary Runoff Basin	**Area (mi^2)**	**Tributary Subbasin**	**Percentage**
		40	6.40%
		42	15.40%
		44	15.70%
		Excluded 496 mi^2	16.70%
3A	954	16	3.70%
		18	96.30%
3B	273	9	7.30%
		11	67.80%
		13	24.90%
3C	108	4	72.20%
		6	27.80%
3D	18	2	100.00%
4	2049	3	2.60%
		5	42.80%
		7	14.50%
		10	13.00%
		12	3.60%
		15	1.50%
		17	22.20%
Horse Creek	1263	21	100.00%
Big Sandy	3624	34	100.00%

6.5. *Streamflow Outlier Months*

Monthly historical streamflows considered to be outlier months in the H-I Model are:

6.5.1. Stateline:

(1) May 1951

(2) June 1951

(3) June 1965 through September 1965

(4) April 1985 through June 1985

(5) April 1987 through June 1987

6.5.2. John Martin Dam:

(1) June 1965 through September 1965

(2) April 1985 through June 1985

6.5.3. At Lamar:

(1) June 1965 through September 1965

(2) April 1985 through June 1985

Certain months are also excluded from statistical comparisons of predicted and observed streamflows because there is no data at those sites: Granada (1950-1985) and Lamar (October 1955-March 1959).

6.6. *Kansas Threshold Demands (1950-79) from RIGHT.DAT and Maximum Stateline Calls by Kansas from RIGHT.DAT*
(all values in acre-feet)

Kansas Threshold Demands (1950-79) from RIGHT.DAT

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1950	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1951	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1952	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1953	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1954	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1955	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1956	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1957	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1958	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1959	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1960	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1961	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1962	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1963	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1964	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1965	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1966	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1967	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1968	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1969	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1970	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1971	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1972	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1973	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1974	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1975	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1976	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1977	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1978	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1979	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1980	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1981	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155

Kansas Threshold Demands (1950-79) from RIGHT.DAT (cont.)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1982	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1983	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1984	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
1985	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155
ave	0	0	0	8390	13466	12258	14696	16356	14876	12113	0	0	92155

[Colo. Exh. 891]

Maximum Stateline Calls (1950-79)
(taken from Dec. 1991 version of RIGHT.DAT)
(all values in acre-feet)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
0	0	0	13500	20500	12500	20000	30000	26000	20000	0	0	142500

6.7. ***Kansas Historical Calls (Post 1980) from RIGHT.DAT*** **(all values in acre-feet)**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1950	0	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1980	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1981	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1982	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1983	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1984	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500

***Kansas Historical Calls (Post 1980) from RIGHT.DAT* (cont.)**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1985	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1986	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1987	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1988	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1989	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1990	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1991	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1992	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1993	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1994	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1995	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1996	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1997	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1998	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
1999	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
2000	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
2001	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
2002	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
2003	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
2004	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
2005	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500
2006	0	0	0	9500	7000	8000	35000	26000	21000	18000	0	0	124500

6.8. *Summary of Input Data Included in RIGHT.DAT*

User No.	IDVT	User Name	TM	WW	JR	NSOUR 1	NSOUR 2	NSOUR 3	WRFAC T	JMPER C	UTYPE	URES	IDS	JRCAN	UMAX	RMAX
1	1	Bessemer	*	*	1	0	15	1	-	-	1	0	0	-	296.0	392.7
2	2	Booth Orchard			1	0	7	1	-	-	1	0	0	-	32.0	30.3
3	3	Excelsior	*		1	0	2	1	-	-	1	0	0	-	75.0	60.0
4	4	Collier			2	0	2	1	-	-	1	0	0	-	26.0	26.0
5	5	Colorado Canal	*	*	2	0	1	3	-	-	1	0	0	-	580.0	756.3
6	6	Rocky Ford Highline	*	*	3	0	8	1	-	-	1	0	0	-	420.0	469.1
7	7	Oxford	*	*	4	0	2	1	-	-	1	0	0	-	140.0	129.4
8	8	Otero	*	*	4	0	2	1	-	-	1	0	0	-	60.0	457.9
9	9	Catlin	*	*	5	0	3	1	-	-	1	0	0	-	330.0	345.0
10	10	Fort Lyon	*	*	7	0	3	3	-	-	1	0	0	-	2000.0	933.0
11	11	Rocky Ford			6	0	2	1	-	-	1	0	0	-	110.0	208.3
12	12	Holbrook	*	*	6	0	2	3	-	-	1	0	0	-	800.0	600.0
13	13	Las Animas		*	8	0	5	1	-	-	1	0	0	-	135.0	207.1
14	14	Baldwin-Stubbs			0	1	0	0	-	-	1	0	0	-	54.1	0.0
15	15	Fort Bent			11	0	7	1	0.099	0.099	1	0	1	-	85.0	229.0
16	16	Keesee			11	0	4	1	0.023	0.023	1	0	1	-	25.0	28.5
17	17	Amity			12	0	3	2	0.502	0.495	1	0	1	-	400.0	783.5
18	18	Lamar-Manvel			13	0	6	1	0.240	0.222	1	0	1	-	225.0	339.8
19	19	Hyde			14	0	2	1	0.013	0.013	1	0	1	-	8.0	23.4
20	20	Manvel			14	0	1	1	-	-	1	0	1	-	91.5	0.0
21	21	XY Graham			15	0	3	1	0.051	0.051	1	0	1	-	61.0	130.0
22	22	Buffalo			16	0	2	1	0.060	0.085	1	0	1	-	80.0	67.5
23	23	Sisson-Stubbs			17	0	3	1	0.012	0.012	1	0	1	-	10.0	25.2
24	24	Pumpers at Stateline			0	1	0	0	-	-	1	0	0	-	186.5	0.0
-	25	John Martin			10	0	1	0	-	-	2	1	1	-	1000.0	
-	26	Lake Henry			2	0	2	0	-	-	2	2	0	5	580.0	
-	27	Meredith			2	0	1	0	-	-	2	3	0	5	580.0	
-	28	Dye			6	0	2	0	-	-	2	4	0	12	800.0	
-	29	Holbrook			6	0	2	0	-	-	2	5	0	12	800.0	
-	30	Great Plains			7	0	1	0	-	-	2	6	0	10	500.0	
-	31	Horse Creek			6	0	2	0	-	-	2	7	0	25	1000.0	
-	32	Adobe Creek			6	0	2	0	-	-	2	8	0	25	1000.0	
25	-	Fort Lyon Storage														
						2	98	29								

Summary of Input Data Included in RIGHT.DAT **(cont.)**

IDVT -- the index for several variable arrays that identifies each variable in the array as being associated with a certain diverter (IDVT = 1 thru NDVT where NDVT = NUSE + NRES)
TM -- transmountain source available
WW -- winter water source available
JR -- River reach from which diversion is made (Section 2.2.1.6)
NSOUR1 -- the number of primary groundwater sources (1 = groundwater use only) (Section 2.2.1.11.)
NSOUR2 -- the number of water rights that can be diverted from the river (Section 2.2.1.12.)
note: Catlin and Las Animas Consolidated each have 1 less right in priority list than NSOUR2 indicates
NSOUR3 -- the number of supplemental groundwater and reservoir sources (Section 2.2.1.13.)
WRFACT -- Colorado Water District 67 user's percentage of John Martin Reservoir releases to Colorado before 1980 (Section 2.2.1.7.)
JMPERC -- Colorado Water District 67 user's percentages of John Martin Reservoir releases from conservation storage to Section II accounts under the 1980 Operating Plan (Section 2.2.1.26)
UTYPE -- user type (1=direct diversion 2=reservoir) (Section 2.2.1.8.)
URES -- number assigned to reservoirs in the H-I Model (Section 2.2.1.9.)
IDS -- diversion above (0) or at or below (1) John Martin Reservoir (Section 2.2.1.10.)
JRCAN -- user number of the canal that delivers water to off channel reservoirs (Section 2.2.1.14.)
UMAX -- the maximum diversion (cfs) (calibrated canal capacity) for the user (Section 2.2.1.16)
RMAX -- the amount of each of the water rights decreed for diversion (cfs) or storage (acre-feet) from the priority list (Section 2.2.1.20.)
note: RMAX for Users 15 - 23 does not include the 1980 rights in the priority list

6.9. *Parameters for Reservoirs from RIGHT.DAT or H-I Model Code*

Reservoir	IDS	UMAX (cfs)	STRMIN (acre-ft)	STRMAX (acre-ft)	JRCAN	NSOUR2	Owner	JRCH	RMAX (acre-ft)	Start Fill (acre-ft)
John Martin	1	1000	0	*		1	25	10	999,999	141,700
Lake Henry	0	580	0	10,915	5	2	26	2	6,353	5,036
							26	2	3,561	
Meredith	0	580	0	41,413	5	1	27	2	26,028	3,337
Dye	0	800	0	2,500	12	2	28	6	4,500	666
							28	6	3,486	
Holbrook	0	800	0	7,472	12	2	29	6	4,276	1,160
							29	6	3,196	
Great Plains	0	500	-42,330	124,561**	10	1	30	7	223,221	77,780
Horse Creek	0	1000	0	26,000	25	2	31	6	26,887	7,517
							31	6	1,113	
Adobe Creek	0	1000	0	87,000	25	2	32	6	61,575	30,834
							32	6	25,425	

Parameters for Reservoirs from RIGHT.DAT or H-I Model Code **(cont.)**

* STRMAX for John Martin Reservoir

Month 1 - Month 91	(Jan 1950-Jul 1957)	–	380,858 acre-ft
Month 92 - Month 146	(Aug 1957-Feb 1962)	–	365,706 acre-ft
Month 147 - Month 223	(Mar 1962-Jul 1968)	–	356,038 acre-ft
Month 224 - Month 266	(Aug 1968-Feb 1972)	–	349,292 acre-ft
Month 267 - Month 365	(Mar 1972-May 1980)	–	348,101 acre-ft
Month 366 - Month 437	(Jun 1980-Dec 1985)	–	341,945 acre-ft
Month 438 - Month 533	(Jan 1986-Dec 1993)	–	337,166 acre-ft
Month 534 - Present	(Jan 1994-Present)	–	335,693 acre-ft

Note: The H-I Model code, as of December 15, 2007, provides that STRMAX is 335,693 AF for Month 534 forward. Any future changes in the STRMAX will result in modification of this part of the H-I Model code.

** Great Plains' STRMAX changed to 223,221 in Nov 1984

IDS – diversion above (0) or at or below (1) John Martin Reservoir (Section 2.2.1.10.)
UMAX – the maximum diversion (cfs) (calibrated canal capacity) for the user (Section 2.2.1.16.)
STRMIN – reservoir storage that cannot be released (dead storage) (Section 2.2.1.22.)
STRMAX – the maximum reservoir storage (Section 2.2.1.23.)
JRCAN – the user number of the canal that delivers water to an off-channel reservoir (Section 2.2.1.14.)
NSOUR2 – the number of water rights that can be diverted from the river (Section 2.2.1.12.)
OWNER – the owner identifier for the storage right (Section 2.2.1.18.)
JRCH – the reach in which the water right is diverted (Section 2.2.1.19.)
RMAX – the amount of each of the water rights decreed for diversion (cfs) or storage (acre-feet) from the priority list (Section 2.2.1.20.)
START FILL – Jan 1, 1950 storage

6.10. *Summary of Input Data in LAND.DAT*

User					% Area Type											Canal		
No.	**User Name**	**AREA**	**AREA2**	**AREA3**	**1**	**2**	**3**	**UC**	**SEV**	**AWC**	**THEATA0**	**Z**	**SEEPFL**	**TAILF**	**SEEPFC**	**LENGTH**	**Seep**	**IRTRCH**	**FME**
1	BESSEMER	21340	19130		32%	0%	68%	1.00	24%	0.15	0.10	3.66	0.07	0.1	0.991562	18	0.141	3	65%
2	BOOTH ORCHARD	1510	1160	600	0%	0%	100%	1.00	24%	0.17	0.10	3.66	0.07	0.1	0.991562	6	0.050	1	65%
3	EXCELSIOR	1810	1940		0%	0%	100%	1.00	24%	0.17	0.10	3.66	0.07	0.1	0.991562	5	0.041	2	65%
4	COLLIER	670	770		0%	0%	100%	1.00	24%	0.17	0.10	3.66	0.07	0.1	0.991562	3	0.025	3	65%
5	COLORADO DITCH IRRIGATORS	46590	35300		76%	0%	24%	1.00	24%	0.17	0.10	4.01	0.07	0.1	0.991562	25	0.191	9	70%
6	ROCKY FORD HIGHLINE	23690	22730		80%	0%	20%	1.00	24%	0.17	0.10	3.81	0.07	0.1	0.991562	41	0.293	7	65%
7	OXFORD	4800	4450		0%	0%	100%	1.00	24%	0.17	0.10	3.78	0.07	0.1	0.991562	9	0.073	5	65%
8	OTERO	7430	5060		93%	0%	7%	1.00	24%	0.17	0.10	3.84	0.07	0.1	0.991562	24	0.184	8	65%
9	CATLIN	17300	16430		34%	0%	66%	1.00	24%	0.17	0.10	3.84	0.07	0.1	0.991562	13	0.104	7	65%
10	FORT LYON	92420	94030		62%	0%	38%	1.00	24%	0.17	0.10	4.07	0.07	0.1	0.991562	54	0.367	14	65%
11	ROCKY FORD	8270	7820		72%	0%	28%	1.00	24%	0.17	0.10	3.84	0.07	0.1	0.991562	8	0.066	7	65%
12	HOLBROOK	15480	14520		72%	0%	28%	1.00	24%	0.17	0.10	3.85	0.07	0.1	0.991562	15	0.119	9	65%
13	LAS ANIMAS CONSOLIDATED	9320	7820	6000	35%	0%	65%	1.00	24%	0.16	0.10	4.11	0.07	0.1	0.991562	10	0.081	10	65%
14	BALDWIN-STUBBS	1260	1520		0%	100%	0%	1.00	24%	0.17	0.10	4.01	0.07	0.1	0	0		6	65%
15	FORT BENT CANAL	5720	5880		17%	0%	83%	1.00	11%	0.17	0.10	4.06	0.07	0.1	0.991562	15	0.119	15	65%
16	KEESEE CANAL	1500	1950		0%	0%	100%	1.00	11%	0.17	0.10	4.11	0.07	0.1	0.991562	4	0.033	12	65%
17	AMITY CANAL	39130	40350		56%	0%	44%	1.00	11%	0.17	0.10	4.06	0.07	0.1	0.991562	43	0.305	18	65%
18	LAMAR CANAL + MANVEL	9780	10740		1%	0%	99%	1.00	11%	0.17	0.10	4.06	0.07	0.1	0.991562	12	0.097	16	70%
19	HYDE CANAL	1290	1610		2%	0%	98%	1.00	11%	0.17	0.10	4.06	0.07	0.1	0.991562	4	0.033	15	65%
20	MANVEL CANAL	0	0		0%	0%	100%	1.00	11%	0.15	0.10	4.06	0.07	0.1	0.991562	6	0.050	16	65%
21	XY GRAHAM CANAL	5240	6410		0%	0%	100%	1.00	11%	0.15	0.10	4.06	0.07	0.1	0.991562	9	0.073	17	65%
22	BUFFALO CANAL	5750	7380		0%	0%	100%	1.00	11%	0.16	0.10	4.06	0.07	0.1	0.991562	11	0.089	18	65%
23	SISSON CANAL	390	540	360	0%	0%	100%	1.00	11%	0.14	0.10	4.06	0.07	0.1	0.991562	3	0.025	18	65%
24	PUMPERS AT STATELINE	2161	6327	5875	0%	100%	0%	1.00	11%	0.15	0.10	4.06	0	0	0	0		18	75%
25	FORT LYON STORAGE								24%						0.991562	26	0.198	9	
	Total Acreage	322851	313867																

***Summary of Input Data in LAND.DAT* (cont.)**

AREA, AREA2 & AREA3 - the irrigated acreages for each user for 1969-1985, 1950-1968 and 1986-1994, respectively (Section 2.3.1.2.). After 1994, the irrigated acreages are updated annually.
AREA - acreage for 1950-68.
AREA2 - acreage for 1969-94.
AREA3 - acreage changed beginning in 1991 for only the four ditches shown.
% Area type (ATYPE - partitions irrigated acreages for each user into three types: surface water only, groundwater only, and surface and groundwater (Section 2.3.1.3.))
1 - land with surface water supply only.
2 - land with ground water supply only.
3 - land with surface and ground water supply.
UC - uniformity coefficient for distributing applied water.
SEV - the percentage of canal and lateral losses and tailwater that is consumed by evaporation or non-crop evapotranspiration (Section 1.5.3.)
AWC - the available soil water-holding capacity by user area (unitless) (Section 2.3.1.9)
THEATA0 - the starting soil moisture by user area (unitless) Section 2.3.1.10
Z - the average rooting zone depth by user area (ft.) (Section 2.3.1.11.)
SEEPFL - a factor to calculate lateral seepage by user (Section 2.3.1.13.)
TAILF - a factor to calculate tailwater by user (Section 2.3.1.14.)
SEEPFC - a factor to calculate canal seepage by user (Section 2.3.1.12).
LENGTH - the canal length by user (100,000 inches) (Section 2.3.1.15)
Canal Seep = 1.0 - SEEPFC**LENGTH.
IRTRCH - the river reach that spills are returned to for each user (Section 2.3.1.6.)
FME - maximum farm efficiency for each user (Section 2.3.1.4.)

6.11. ***Reach Allocations***

	River Reaches																			
BESSEMER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return	65.00	25.00	10.00																		
gw recharge (gw resp)	64.65	23.65	11.70																		
gw recharge (sw resp)	65.07	24.68	10.25																		
BOOTH ORCHARD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return	100.00																				
gw recharge (gw resp)	99.41	0.60																			
gw recharge (sw resp)	99.53	0.47																			
EXCELSIOR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return	30.00	70.00																			
gw recharge (gw resp)	70.85	29.10	0.05																		
gw recharge (sw resp)	45.97	53.87	0.16																		
COLLIER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return		35.00	65.00																		
gw recharge (gw resp)	0.02	25.96	74.01																		
gw recharge (sw resp)	0.04	41.72	58.24																		
COLORADO DITCH IRRIG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return			2.00	1.00	5.00	28.00													64.00		
gw recharge (gw resp)		0.04	29.30	18.22	11.16	9.23	0.01		3.89										28.15		
gw recharge (sw resp)			3.70	2.92	5.13	18.65	0.02		4.20										65.36		
ROCKY FORD HIGHLINE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return				12.00	14.00	17.00	57.00														
gw recharge (gw resp)				21.53	16.09	32.36	29.98												0.03		
gw recharge (sw resp)				23.35	15.68	18.52	42.44												0.00		

Reach Allocations **(cont.)**

	River Reaches																			
OXFORD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return				25.00	75.00																
gw recharge (gw resp)				51.16	41.89	6.95													0.01		
gw recharge (sw resp)			0.01	46.21	49.45	4.33															
OTERO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return					8.00	17.00	75.00														
gw recharge (gw resp)				8.42	39.17	0.72	51.70												0.00		
gw recharge (sw resp)				0.45	5.62	10.16	83.77	0.00											0.00		
CATLIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return						15.00	85.00														
gw recharge (gw resp)					0.10	20.31	79.51	0.02											0.06		
gw recharge (sw resp)					0.02	11.97	87.99	0.01											0.00		

FORT LYON	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return							2	5	7	15	8	17	29	17							
gw recharge (gw resp)							5.67	21.90	16.80	20.69	3.25	6.39	14.91	10.40							
gw recharge (sw resp)							0.68	6.36	7.96	12.50	7.10	13.30	29.72	22.39							
gw recharge (cn resp)							4.20	13.70	23.60	23.10	10.00	5.10	14.50	5.80							
ROCKY FORD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return						1.00	99.00														
gw recharge (gw resp)						3.30	96.69	0.01													
gw recharge (sw resp)						0.97	99.03	0.00													
HOLBROOK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return							20.00		44.00											36.00	
gw recharge (gw resp)						0.71	61.61	0.00	20.78											16.89	
gw recharge (sw resp)						0.00	15.00		46.90											38.10	

Reach Allocations **(cont.)**

	River Reaches																			
LAS ANIMAS CONSOLIDA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return									60.00	40.00											
gw recharge (gw resp)								0.15	69.11	30.73											
gw recharge (sw resp)								0.03	52.25	47.72											
BALDWIN-STUBBS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return					33.00	67.00															
gw recharge (gw resp)				0.24	35.34	63.47	0.00												0.95		
FORT BENT CANAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return												1.00	65.00	30.00	4.00						
gw recharge (gw resp)											0.00	0.96	91.58	7.45	0.00						
gw recharge (sw resp)											0.08	1.60	92.09	5.84	0.40	0.00					
KEESE CANAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return												98.00	2.00								
gw recharge (gw resp)										0.00	2.49	97.32	0.19								
gw recharge (sw resp)										0.00	1.17	78.85	19.98								
AMITY CANAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return													5.00	7.00	3.00	10.00	33.00	42.00			
gw recharge (gw resp)												0.04	12.08	7.31	5.03	7.61	29.89	38.05			0.00
gw recharge (sw resp)													5.16	7.77	6.03	10.26	32.44	38.34			0.00
gw recharge (cn resp)												0.60	14.80	18.10	28.00	14.90	16.80	6.80			
LAMAR CANAL + MANVEL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return														32.00	25.00	36.00	7.00				
gw recharge (gw resp)													5.60	17.83	33.23	25.61	17.64	0.09			
gw recharge (sw resp)													3.12	29.39	30.22	23.24	13.96	0.06			

Reach Allocations **(cont.)**

	River Reaches																			
HYDE CANAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return														100.00							
gw recharge (gw resp)													0.27	71.91	27.67	0.15					
gw recharge (sw resp)													0.00	75.90	23.94	0.15					
XY GRAHAM CANAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return																30.00	70.00				
gw recharge (gw resp)														0.01	4.88	33.19	60.77	1.16			
gw recharge (sw resp)														0.00	2.38	31.79	63.39	2.45			
BUFFALO CANAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return																	15.00	85.00			
gw recharge (gw resp)															0.00	0.07	37.61	62.04			0.28
gw recharge (sw resp)																0.03	23.27	76.42			0.29
SISSON CANAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return																		100.00			
gw recharge (gw resp)																	3.87	96.02			0.11
gw recharge (sw resp)																	3.48	96.26			0.26
PUMPERS AT STATELINE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	MER	CHER	SL
sw return																		100.00			
gw recharge (gw resp)							0.04	3.36		0.05	3.92						0.78	88.03			3.82

MER – Lake Meredith
CHER – Lake Cheraw
SL – Stateline

APPENDIX C.2

Usable Flow Methodology

The Durbin usable flow method with the Larson coefficients consists of coefficients that are applied to Stateline flow as simulated by the H-I Model and determines the amount of simulated Stateline flow that is usable for diversion and groundwater recharge in Kansas (see Volume II of the First Report of Arthur L. Littleworth, Special Master, at pages 293-94). The Durbin usable flow method with the Larson coefficients is as follows:

1. *Larson Coefficients*:
    a. From April 1 through October 31 (Summer), 72 percent (%) of the Stateline flow as simulated by the H-I Model is usable for diversion and 9.9% of the simulated Stateline flow is usable for groundwater recharge, for a total of 81.9%, subject to the limits set forth below.
    b. From November 1 through March 31 (Winter), 25% of the Stateline flow as simulated by the H-I Model is usable for diversion and 9.9% of the simulated Stateline flow is usable for groundwater recharge, for a total of 34.9%, subject to the limits set forth below.
2. *Monthly Limits*:
    a. During the Summer, the simulated Stateline flow usable for diversion is limited to 30,000 acre-feet per month.

b. During the Winter, the simulated Stateline flow usable for diversion is limited to 7,500 acre-feet per month.

c. The simulated Stateline flow usable for groundwater recharge is limited to 100,000 acre-feet per month.

3. *Seasonal Limits*:

a. During the Summer, the simulated Stateline flow usable for diversion is limited to 140,000 acre-feet.

b. During the Winter, the simulated Stateline flow usable for diversion is limited to the 40,000 acre-feet.

4. *Steps to determine Annual Calculations of depletions and accretions to Usable Stateline Flow in accordance with the procedures described in Appendix B and the Durbin usable flow method with the Larson coefficients*:

a. Update the H-I Model and make the Compact run and the Historical run as described in Appendices B.1 and C.1.

b. For each H-I Model run, multiply the simulated monthly Stateline flow by 72% during the Summer, subject to the monthly and the Summer limits described in paragraphs 2a and 3a above, and add 9.9% of the simulated monthly Stateline flow for these months subject to the monthly limit described in paragraph 2c above.

c. For each H-I Model run, multiply the simulated monthly Stateline flow by

25% during the Winter, subject to the monthly and Winter limits described in paragraphs 2b and 3b above, and add 9.9% of the simulated monthly Stateline flow for these months subject to the monthly limit described in paragraph 2c above.

d. Subtract the Usable Stateline Flow for the Historical run from the Usable Stateline Flow for the Compact run on a monthly basis to determine the amount of the depletion (positive result) or the accretion (negative result) to Usable Stateline Flow.

e. The sum of the monthly depletions or accretions to Usable Stateline Flow determined pursuant to paragraph 4d shall then be used in the Annual Calculations, subject to the analysis for the limit on accretions in accordance with the procedures in Appendix D.